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MAY 1920

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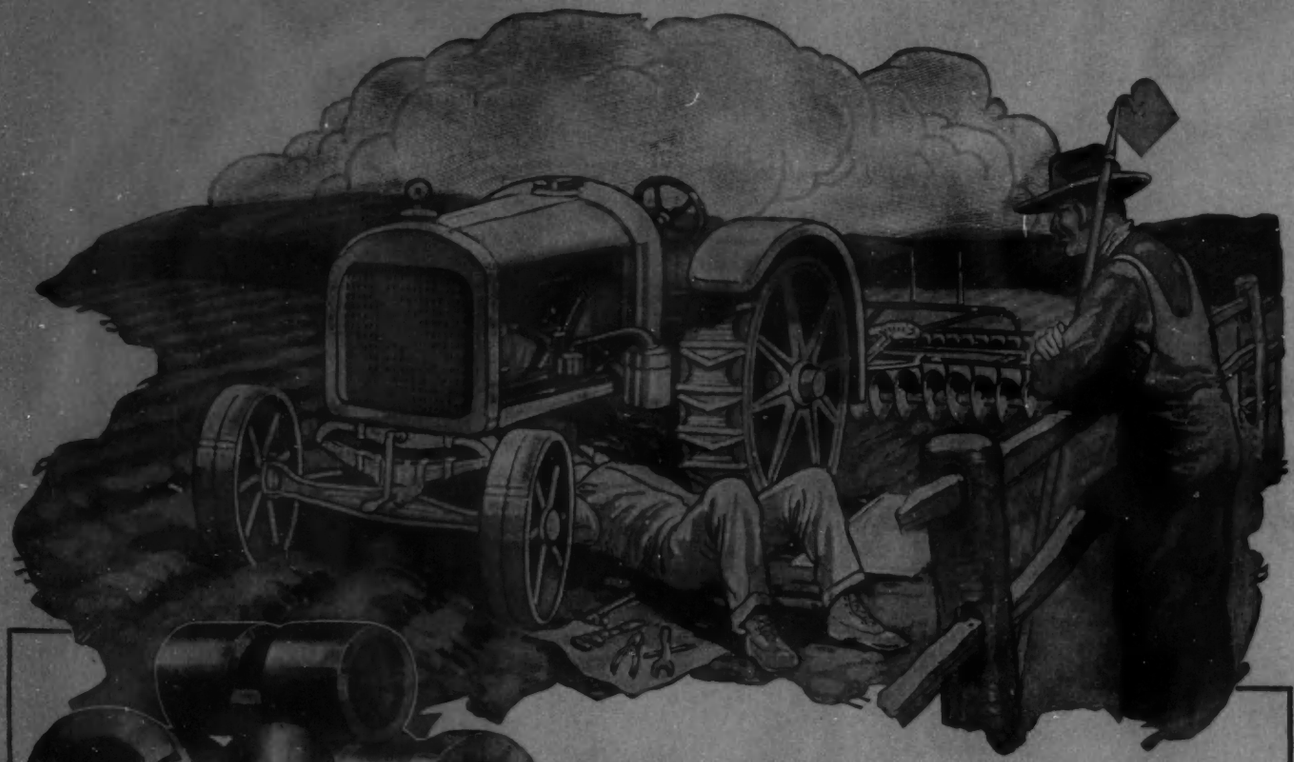

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THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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Summer Meeting, Ottawa Beach, June 21 to 25

THE 1920 Summer Meeting will be held at Ottawa Beach, Mich. This attractive resort was selected because of its convenience to the center of the automotive industry, its facilities for water sports and grounds for exhibits, all of which are important features to be considered. The number of requests already received for accommodations indicates that the selection meets with the hearty approval of the membership. One of the most attractive features of Society meetings is the opportunity for renewing acquaintances and old friendships as well as making new ones. A large attendance increases this opportunity. It is expected that all precedents in this regard will be broken at the 1920 Summer Meeting.

Standards and Business Session

During the morning and afternoon of the first day, Monday, June 21, there will be Standards Committee sessions. Important reports will be presented for approval by various Divisions of the committee. It is urged that all members and company representatives serving the Society in standards work be present at these sessions. A program of the work to be done will be sent to all members well in advance of the meeting.

The semi-annual business session will be held Monday evening. Some matters of unusual importance to the welfare of the Society will be considered, including the constitutional amendments proposed at the last meeting of the Society and described in the January and April issues of THE JOURNAL. There will be a discussion of the matter of the proposed adoption of the metric system in this country, to secure expression of representative opinions. All members are requested to attend.

A very attractive and interesting sports program has been arranged for the entire meeting, starting at 3 o'clock on Monday, and continuing each afternoon including Friday. The baseball series and tennis and golf tournaments will start on Monday. Age classifications for athletics will result in more closely contested events and a greatly increased number of prize awards. First, second and third prizes will be awarded in each of the tournaments. Several new games will be introduced for the first time.

One of the most successful features of the 1919 Summer Meeting was the automotive apparatus exhibits. Arrangements already made indicate that this year these exhibits will be even more valuable, as well as intensely interesting. The instructive value of an exhibition is always great, particularly when, as will be the case this year, the apparatus is selected with the idea of illustrating technical points which the members are diligently studying. The exhibits will in many cases have close relation to matters presented in papers given at the morning sessions of the meeting. Some of them will be of a spectacular nature. Major Azel Ames has been appointed by the Meetings Committee to take charge of exhibit arrangements.

Professional Sessions

On Tuesday, June 22, at 10 o'clock the Fuel Session will convene. Fuel is a subject of vital importance to the industry, and papers dealing with its most potent factors will be presented. The S. A. E. Committee on the More Efficient Utilization of Present Fuels has prepared a report embodying recommendations to automotive engineers endeavoring to relieve the engine fuel situation. A demonstration engine test will be conducted at the meeting, illustrating some of the committee's suggestions.

On Wednesday, June 23, the Transportation Session will be the occasion of the presentation of papers dealing with problems of land vehicle operation, aerial freight and passenger service, and inland water transportation. The discussion of these essential factors of civilization should result in very valuable suggestions and many specific basic data.

On Thursday, June 24, the Farm Power Session will be held. An opportunity will then be afforded for agricultural engineers to discuss with the automotive engineers the problems of application of power on the farm. There will be a symposium on plowing speeds, prepared by engineers particularly well qualified to discuss the matter. A paper on farm power machinery is expected to prove very interesting and of practical help to designers of this equipment.

Friday morning, the final day of the meeting, will be devoted to consideration of points involved in quantity and relatively small production. The human element entering into production and the factory organization necessary for most efficient work will receive intensive treatment. The addresses for this session have been carefully selected with a view to assisting production engineers in the solution of their knotty tasks. With plans for enormous output and with unprecedented obstacles in transportation facilities, the further handicap of labor troubles in production should be given very careful study for possible elimination.

Organization of Air Service Mechanics' Regiments

By C. M. Tichenor[1] (*Member*) Buffalo Section Paper

IT is a well-known fact that when the war was declared this country was not prepared to put into the field the enormous number of planes and required amount of auxiliary equipment to make our entry into the war effectively felt. It was necessary for this country to secure planes and engines to be delivered almost immediately, and orders were placed in France for $80,000,000 worth of planes and engines, with which to equip our first combat squadrons and the various training centers in France, until our manufacturers should be in a position to produce the required planes. The late Col. R. C. Bolling was sent to France to supervise the construction of these planes.

To complete the contracts in France it was necessary to take men from the front for use in the factories. As the German advance came nearer to Paris, these men were sent to the front again, and we were called upon to supply men to complete the work. This request came through the French War Office to General Pershing, who in turn sent the following cablegram to this country:

> For the Chief of Staff.—French Ministry of War states that in view of large orders for aviation material placed by our Government with French contractors, they will find great difficulty in meeting our demands on account of shortage of trained mechanics. They state that to expand production and allow them to complete American program, it will be necessary to provide their industries with extra labor drawn from their automobile sevice. When orders were placed French stated they would have no difficulty in meeting labor situation; they now suggest most practical way to provide labor would be for us to bring over chauffeuis and mechanics for their automobile service, replacing a corresponding number of French for plane construction. Number requested estimated at 16,000. French suggest possibility of their providing ships for transportation, thus avoiding interfering with our shipping program. Arrangements could be made to receive these men at ports not used by expeditionary forces and prevent congestion at our bases. Suggest Brest or La Pallice. Personnel should consist of 10 per cent automobile mechanics, chauffeurs, cooks, etc. These should be organized same as Cavalry Division supply train with 10 per cent extra personnel for replacements. After further considering with Bolling recommend favorable view of French request, providing they are in position to handle transportation of personnel asked for. (Signed) PERSHING.

The War College favorably considered the request and Col. C. G. Hall, a regular army officer, who had seen some twenty-five years in the service, was selected to head the organization of the regiments. With him was associated Col. Henry B. Joy, formerly of the Packard company. I had been serving as Chief of Engine Inspection and was transferred to duty with Colonel Hall.

The making of plans for the kind of an organization that was wanted in Europe was very difficult, for in looking up the various Army organization-tables it was found that nothing had ever been attempted where the technical and military branches of the work were combined in a single unit as large as a regiment. Careful study was required to organize regiments properly balanced from both military and technical standpoints, technical ability always being borne in mind as the foundation of success. Nothing worked more smoothly or efficiently, however, than the combined efforts of the military and technical officers of the regiments.

There was little information with which to work, but an organization was tentatively planned and later adopted which included 3501 men in each regiment. Each company consisted of 168 men, two technical lieutenants and a military captain; four companies to a battalion. At the head of each of the four battalions was a technical major and a commanding military major; four battalions to a regiment. All were directly responsible to the lieutenant-colonel, who in turn served under the commanding officer of the regiment, who in each instance in the four regiments was a West Point officer. The object of having both military and technical officers was that the former should have charge of the military affairs of the regiment, seeing that the men were properly clothed and fed, and maintaining military discipline, and that the industrial officers should devote their entire efforts to technical and industrial matters.

All industrial affairs were supervised by the lieutenant-colonel, whose staff was composed of the four technical majors and three captains, one an expert on internal-combustion engines, another on carburetion and ignition, and the third a man with very broad experience with airplanes. The plan was approved by the United States War College in December, 1917.

Actual Work Begun

Some officers were immediately commissioned in Washington and ordered to scour the various camps for the best mechanics available as required by the organization chart and to have these men transferred forthwith to Camp Hancock, Augusta, Ga. I was appointed to head an examining board to secure the shop executives or industrial officers for the four regiments.

I had sent a number of telegrams to my friends in the automobile industry in Detroit in the hope that they would aid us in securing suitable industrial officers. Naturally, we were not welcomed by the manufacturers in the various cities, as they were having great difficulty in retaining the men they absolutely required to carry on their work. The only way we could secure men of the desired type was to advertise in the newspapers. In eight or nine days we secured some forty-five officers, after interviewing approximately five hundred. The men selected were general foremen, departmental foremen and superintendents. They had wide experince in engineering, machine-shop work and assembling. We chose them very carefully.

[1]Assistant general manager, Pierce-Arrow Motor Car Co., Buffalo.

We returned to Washington Dec. 17, 1917. Whether it was because we were so good at organizing, or because we had done a poor job, we do not know, but we were immediately ordered to swing around the circuit of Washington, Chicago, Detroit, Indianapolis, Toledo, Cleveland, Boston, New York and Philadelphia, and to accomplish this in twenty days and get the required quota of officers. We arrived in Chicago Dec. 24, working Christmas Day, and continued every day, including Sundays and New Year's Day, traveling by night. Upon arriving in Washington we found we had secured more officers than were actually required. The names of the surplus officers were turned over to other branches that were organizing, air squadrons, ordnance depots, etc. We were then ordered to Camp Hancock. We had started on Dec. 9, 1917, to secure men and officers, and before Jan. 1, 1918, there were approximately 3100 men and 85 officers in camp, all trade-selected, and we were well on the way to complete one regiment during the first week in January.

The first regiment did not receive orders to move until Jan. 22, and I was extremely disappointed to find that my orders read to supervise the organization of the entire four regiments, together with Colonel Joy, and to accompany the last regiment overseas. Enlisted men for the second regiment were arriving in lots of one to two hundred. Very often we would meet their trains in the middle of the night; their tents were pitched and they found a shelter and a warm meal awaiting them in camp.

The Officers' Training School

While this regiment was mobilizing, an industrial training school was started for officers. The officers left their respective companies and battalions long enough to get down to industrial matters for a daily meeting of about two hours. This is a most important point, and I wish to emphasize it. The purpose was to let the foremen and workmen, the officers and the enlisted men, know exactly what we were trying to accomplish. This was really the keynote of the extraordinary success of the air-service mechanics' regiments; the men knew at all times what the officers were striving to attain, what work was to be accomplished as an organization rather than the individual accomplishments of a smaller unit of the regiment. The three captains, or instructors in their particular branches of the work, taught the officers of the regiment, during the various meetings, both technical matters and what the regiment would be called upon to do abroad. Notes were made during these meetings and mimeographed copies were distributed to the officers shortly after their close. This plan was carried out while the men were in camp and to some extent while abroad. The non-commissioned officers, or foremen, and the enlisted men, the mechanics and workmen, were in turn instructed by the officers and at all times were thoroughly conversant with the entire job. By thus taking the men into our confidence and establishing an industrial pride in what the regiment was going to accomplish, we laid the foundation of one of the smoothest-working organizations in the entire A. E. F. The point I wish to bring out is that of letting the workmen know by personal contact with and instruction from the foremen, exactly what was to be accomplished, not only by departments, but how the individual work would affect the fellow along the line in the next department, and how he should help the other fellow along rather than do his own job absolutely correctly and neglect cooperation between departments which is so essential to the proper functioning of a well-organized plant.

On Feb. 17 we reported to Washington that we were up to strength and ready to move. Orders were immediately received to entrain for the port of embarkation, and 2000 of the regiment were ordered to break camp Feb. 18. Officers and men were busy nearly all that night and the usual expectation of overseas service, coupled with anxiousness to get started made our part of Camp Hancock seethe with activity. At 5:00 a.m. all surplus food had been turned in to the quartermaster, all ordnance property issued, inspections held, barrack bags packed, fires put out, company streets cleaned and the decks cleared for movement. The main street through the camp was piled high with the barrack bags; trucks were ready, preceding the marching column, which moved out of camp as one body. It was one of the finest sights imaginable to see the precision and exactness with which the men assembled their equipment and left camp without any confusion whatever.

Planning a Foreign Base

Upon returning to Washington, I found that we were called upon to organize the personnel and to secure machinery and equipment for the American Air-Service base at Romorantin, France, where all American planes were to be assembled, from which base Col. S. D. Waldon, formerly of the Packard company had just returned. We laid out the buildings for this base, which covered an area of some 1,700,000 sq. ft., including machine and woodworking shops, repair and assembly equipment for 100 planes per day, together with barracks for 14,000 men. Machine tools and all operating equipment were ordered and plans instituted to complete this base with everything necessary to carry on the enormous amount of work which would be required of it later in the war. At this time a big drive at Amiens started and it was vitally important to ship only combat troops overseas. For this reason the third and fourth regiments were delayed, and by the time the pressure was relieved on combat organizations, our Romorantin project had developed to the point where we required the men to carry out the work.

The third and fourth Air Service mechanics' regiments were transferred from Camp Hancock to Camp Green, Charlotte, N. C., and we immediately shipped to the latter point airplanes and engines for instruction work, and all available information on every type which we might be called upon to handle. To instruct the officers and men further, we sent fifty-five officers to the various plants, Packard Motor Car Co., Marmon, Fisher Body Corporation, etc., to obtain first-hand information on engines, planes and parts. After spending approximately forty-five days at these plants, the officers returned to Camp Green and instructed the enlisted men of the two regiments. The result of this schooling was that we had two regiments or 7002 men as thoroughly instructed in the assembly and maintenance of planes and engines as was humanly possible. During this instruction period the buildings at Romorantin, France, were being constructed and machinery shipped overseas and installed. Major Sumner, who was with me on the examining board, was ordered overseas and later assigned as commanding officer of this post, the industrial work being supervised by Major Allen.

Because of the delay in getting our third and fourth regiments priority orders, the Romorantin base was

compelled to get mechanics from our second regiment, then overseas. In the first week of July, 1918, the third and fourth regiments were ordered overseas, as well as some twenty officers of the regiments who were with me in Washington. It was found that the third and fourth regiments were not required upon arriving at Romorantin. Some of the companies were assigned to duty in the zone of advance and some to Joseph Bell, establishing one of the most important Air-Service bases, Issodun. Other companies were under Major Ramsey at Air Depot No. 1, and some went to England to the Handley-Page plant under the command of Colonel Hall. The other companies of the third and fourth regiments were assigned to duty at Romorantin.

What the Regiments Accomplished

The first regiment arrived in France early in February, 1918, and the second early in March. At this time the English Army was in need of mechanical help and two battalions, approximately 1600 men, were ordered for duty with them in Flanders. The remainder of the first regiment and the majority of the second were assigned to the French Army. These American mechanics handled at the French shops practically every kind of mechanically-driven device used at the front. They were distributed from Toul to Flanders to work on airplanes, balloons, winches, tanks, guns, everything that required mechanical care and maintenance.

It is very hard to appreciate the difficulty under which our American mechanics labored. The difference in language was, of course, a stumbling block. The manufacturing and maintenance methods of the French, although accurate and rather laboriously well done, were so foreign to the American idea of similar work that at the start diplomatic handling and considerable patience on the part of everyone were required. It was a matter of the foreign mind educated on hand-made work, slowly but effectively lined up with the American mind trained to produce in quantity in a minimum amount of time. How well this combination succeeded can be judged by the absolute cohesion of the two kinds of mind, and the feeling of good fellowship which prevailed between the American and the French mechanics. Our men were very much admired by the French for their extraordinary work, and it was a source of great satisfaction, particularly to the organizing officers, to receive expressions of commendation from the American and the French General Headquarters and the British Field Headquarters on the work accomplished by these American mechanics.

I believe firmly that there is something lacking in our present method of taking a man into a manufacturing plant considering him only as a cog in the big machine, failing to instruct him through the foreman which way is best adapted to the particular plant concerned, either by printed bulletins, leaflets, or personal contact in the form of departmental workmen's meetings, pointing out to him that the better his work is the more smoothly his department will function, and that in turn the ultimate result after the necessary cooperation is established will make the organization larger and consequently result in his being a bigger man, particularly in salary, as the firm grows in importance and output. In this way the managements can have a source of trained men from which to select foremen and other executives, men trained with a broad viewpoint and better insight into the results which are desired, as were the mechanics in the Air-Service regiments. I cannot emphasize too strongly that American manufacturers should devote more attention to the training of their workmen than is generally practised in most organizations. If you engineers, many of whom have direct charge of such bodies of men, will bring these points directly before the workmen, I believe your success will be as conspicuous as was ours with the regiments I have described.

PERSONS PER MOTOR VEHICLE IN THE UNITED STATES

ON Dec. 31, 1919, there was registered in the United States, exclusive of Alaska and the insular possessions, one motor vehicle for every 13.8 inhabitants. This figure is given in a table compiled by the Omaha Chamber of Commerce from information secured directly from the person in charge of automobile vehicle registration in each State. Motor trucks and passenger cars are included, as the two types of vehicle are not separated in the majority of the States. The total number of vehicles registered was 7,459,607, which based on a population of 103,266,024, gives the figure stated. California takes first rank among the States with the smallest number of persons per vehicle, 6.2, and is closely followed by Nebraska and South Dakota with 6.8 persons. Iowa and Montana rank next with a ratio of one vehicle to each 7.9 inhabitants.

A study of the table reveals a number of interesting facts. For example, New York, with the largest number of inhabitants and the greatest number of vehicles registered, 10,460,182 and 560,811 respectively, ranks thirty-fifth among the States with one vehicle for every 18.6 inhabitants. Pennsylvania, with a population of 8,660,042 and a registration of 490,337 vehicles, or one vehicle for every 17.6 inhabitants, is thirty-fourth. Illinois, ranking third in population with 6,234,995 inhabitants, and fifth in the number of registrations, 478,438, is twenty-second with one vehicle for every 13 persons. Ohio, which has fourth place in population, 5,212,085, and second in the number of registrations, 511,500, is in the fourteenth place with a ratio of one vehicle to every 10.1 inhabitants. Nevada, which is the smallest from the viewpoints of population and the number of registrations, has the nineteenth place with one vehicle for every 12.3 inhabitants, the figures for this State being 110,738 inhabitants and 9305 vehicles registered. Mississippi, with a population of 1,976,570 and a registration of 48,000 vehicles, has the greatest number of persons per vehicle of any of the States, the figure being 41.1.

The details of the five leading States are given in the accompanying table.

State	Motor Vehicles Registered	Population	Inhabitants per Motor Vehicle
California	493,463	3,029,032	6.2
Nebraska	189,350	1,284,126	6.8
South Dakota	104,628	716,972	6.8
Iowa	279,677	2,224,771	7.9
Montana	59,312	472,935	7.9

Motor Transport Corps Spark-Plug Specifications

TO provide definite specifications for parts and materials to be purchased by the Motor Transport Corps for use on military equipment, the Corps, in cooperation with the Bureau of Standards and the Society, is preparing specifications covering the tests and qualifications required of commercial material available in the open market. The specifications are being carefully prepared at meetings held in Washington and by submitting them to the several Divisions and Subdivisions of the Society's Standards Committee. The industries are being requested to criticize the specifications freely and to offer constructive suggestions for consideration in the final drafting of the specifications.

The following spark-plug specifications have recently been approved by the Motor Transport Corps and are now effective:

Specification for Spark-Plugs

GENERAL

This specification covers the type of spark-plugs used in engines of motor trucks and automobile passenger cars.

Plugs shall preferably be two-piece construction. Plugs with other than conventional shaped spark-point terminals must be submitted to the Motor Transport Corps for approval of each type.

To be approved for purchase a type of spark-plug must conform to the specifications and tests described below; and must also have given satisfactory service for at least 100 hr. total running time on the road or in dynamometer test, at the discretion of the Motor Transport Corps, on an engine of a type to be specified by the Motor Transport Corps. The running test shall include idling and light, average and full loads.

Test of spark-plugs shall be conducted at the option of the Motor Transport Corps.

The laboratory tests shall be made either at the Bureau of Standards, Washington, or by any other recognized authority to be designated by the Motor Transport Corps.

The tests described below shall be made on each new type of spark-plug submitted for approval, and also on plugs of approved types at such other times as may be desired by the Motor Transport Corps, to insure the maintenance of the quality of the plugs delivered. In either case ten plugs shall be submitted for engine tests, and ten plugs and ten insulators without shells or electrodes for laboratory tests.

In cases where the plugs contain types of insulator which have been already approved, the tests on the bare insulator may be waived at the discretion of the Motor Transport Corps.

CONSTRUCTION AND DIMENSIONS

The threaded portion of the plug shall conform to the S. A. E. standard dimensions for ⅞-in. and metric spark-plug threads, and to the standard of the American Society of Mechanical Engineers for ½-in. pipe thread, to within their respective tolerances.

The gap between the electrodes shall be between 0.5 and 0.7 mm. (0.020 and 0.028 in.) and the design and construction shall be such as, in the judgment of the inspector, to maintain this spacing under all conditions of use.

Terminals with 8-32 threads shall be of the screw-and-nut construction, and the nut shall be adapted to take either an eyelet or a split-spade terminal.

TESTS

Dielectric Strength. Three of the sample insulators shall withstand for 2 min. without puncture an effective alternating voltage of 25,000 applied between the central electrode and a metal band around the outside of the insulator. This test is to be made while the insulator is immersed in oil at room temperature. The passage of a spark over the surface of the insulator shall not be counted a failure unless it occurs at less than 20,000 volts.

Resistance to Mechanical Vibration. Two of the assembled plugs shall be tested in the manner described below and shall show no cracks or other signs of mechanical damage after 25,000 blows. The plugs are screwed firmly into the sides of a steel block 6 by 6 by 9 cm. (2.36 by 2.36 by 3.54 in.) which is carried on the end of an arm 24 cm. (9.44 in.) long. By means of a pair of cams the block is raised 19 mm. (0.74 in.) and allowed to fall upon a hardened steel rail. A pair of tension springs assist in pulling the block downward and give it a velocity of about 200 cm. (78.74 in.) per sec. at the instant of impact.

Resistance to Thermal Cracking. Five insulators with shell and central electrode removed shall be brought to a uniform temperature of 150 deg. cent. (302 deg. fahr.) and then quenched in water at room temperature and examined for cracks by soaking for several hours in an alcoholic solution of eosin.

After the aforesaid quenching and soaking no cracks shall be visible to the naked eye. This test shall not apply to mica plugs.

Gas Tightness. Six of the completed plugs shall be screwed into a pressure bomb containing air at a pressure of 15 kg. per sq. cm. (225 lb. per sq. in.) and immersed in a bath of oil heated to 150 deg. cent. (302 deg. fahr.). Under these conditions the average volume of air leaking through the plugs shall not exceed 1 cc. (0.06 cu. in.) per sec. and that through the worst plug shall not exceed 2 cc. (0.12 cu. in.) per sec. This test shall be made both before and after the engine test.

The Society has been requested by the Motor Transport Corps to bring these specifications to the attention of all manufacturers interested in them, with the request that their product be submitted to the Motor Transport Corps for test as soon as possible to prevent congestion in the inspection and testing of spark-plugs, and the resultant loss of time in approving different makes at any time in the future. Full information can be had by writing to the Engineering Branch, Motor Transport Corps, Washington.

Addresses at Akron Dinner

IN connection with the joint meeting of Cleveland and Detroit Sections which was held at Akron, Ohio, the members attending were given a dinner by the Goodyear Tire & Rubber Co. in its general office building. P. W. Litchfield and F. A. Seiberling, vice-president and factory manager, and president respectively of the company, made addresses.

ADDRESS OF P. W. LITCHFIELD

THE progress of civilization in any country is dependent upon its religion, education, form of government, natural resources and transportation systems. The transportation systems of a country have a very important part in broadening the education of the country, and also in developing its natural resources. As an illustration of that I will briefly review the history of the rise and fall of nations as a corollary to their transportation systems.

The first transportation was by walking. Man never traveled very far then and each little group was almost isolated from other groups. Then came transportation by domestic animals, bringing forward Egypt, Babylonia and Persia. The new transportation aboard boats brought Greece to the front, and larger boats advanced Rome, which was the first nation to start inland again by building good roads, making transportation by domestic animals more efficient. Then followed the sailing ship. Those who first took advantage of that became the leading nations. The cities of Genoa and Venice had then the largest sailing ships in transportation outside of inland waterways, such as the Mediterranean and Red Sea. Transportation over the ocean made England and Spain conspicuous as world powers, and they so remained until the beginning of the nineteenth century, when the steam engine was invented. This brought forward countries which did not have so large a sea-coast but more internal territory to develop, such as our own country. Affairs so remained until our day, when the development of the internal-combustion engine and the pneumatic tire have made possible the automobile, now the form of transportation that has partly taken the lead, will stop the development of others and take their place.

I will first mention the relative merits of the solid and the pneumatic tire on motor vehicles. First we had the bicycle with a steel tire; then with a solid and then with a pneumatic tire. People said that the pneumatic tire would not do because it punctured and because it cost more. That, however, was no reason why the bicycle should continue on solid tires. Pneumatic tires gave the bicycle a greater usefulness that alone was sufficient for the change. The carriage followed. The development of the pneumatic tire practically eliminated the horse, on account of the speed of transportation by the passenger automobile. Today, many more passengers per mile are carried by automobiles than by rail transportation.

The transportation of merchandise did not follow rapidly the transportation of passengers. When it did follow, trucks were equipped with solid tires. In spite of the fact that every other vehicle had changed from solid to pneumatic tires, after a very short period, there seemed to be a general impression that while this was true of almost everything else, it did not apply to the truck. Many people contended that the truck was the logical field for the solid tire and that the pneumatic tire had no place there. It is possible, in fact probable, that the reason the solid tire maintained such headway on the truck is that the pneumatic-tire development did not keep pace with the development of the truck. We now know that with the introduction of cord instead of fabric in tire construction, the limit of successful pneumatic tires must not be loads carried by the ordinary 4½-in. touring-car tire, but increase up to 12-in. and probably larger sizes.

So long as the automobile was developed only to the extent of replacing the horse-drawn carriage, the automobile industry did not grow beyond that volume. As the automobile was developed further and further, it became so efficient that it created for itself a need and established an industry many times larger than that which it was designed to replace. This was accomplished by the pneumatic tire.

The truck industry is in exactly the same position as the passenger car was. It is at present equipped with solid tires. Practically, it has only replaced the horse-drawn truck, but the efficiency of the truck when properly designed for and equipped with pneumatic tires will increase its field of usefulness in transportation of merchandise in the same proportion that the passenger automobile increased traffic volume over that of the carriage which it replaced.

The Obsolescent City Street Car

I shall now discuss the problem of street railway transportation. My first lesson in physics was that two bodies cannot occupy the same space at the same time. You have only to go into any crowded city to see what is happening to the city transportation system when the automobile and the street car try to occupy the same space at the same time. One or the other must go. It was a practical thing, when the streets were not crowded, to place two rails along the center of the street and transport the bulk of the people in cars run on those rails. The speed was good and the cars interfered with nothing in particular. But with the advent of the automobile we find a very different situation. The streets are now crowded, and this condition will get steadily worse and cannot be made better so long as both forms of transportation try to occupy them. It is really ridiculous that one person, in a crowded thoroughfare occupied by thousands hurrying from one place to get to another, can step out of a street car into the middle of the street and stop everything for two or three blocks while he walks through the intervening space to get to the sidewalk. It is not the number of vehicles that can get through a street abreast, it is the time that those vehicles are occupying that street. If traffic can be kept in motion instead of being continually stopped, the same amount of people and the same number of vehicles can go through that street in a third of the time, or, three times as many vehicles can go through it in the same time. Therefore, it will be necessary in the future to provide a transportation system in which the only vehicle that stops is the one that wants to stop, while everything else goes on, and that vehicle must stop at the curb.

It is quite evident that it is the street car that must go. Cities cannot afford to widen their streets indiscriminately or put in more streets; there is too much fixed

investment. What they must do is to eliminate one form of transportation by giving another the right-of-way on the streets. I do not know how long it will take us to learn this lesson, but it must be learned. It is being learned in other places. The streets of London are narrow and crooked, yet they are carrying more transportation than any streets in any of our own cities, because they realize that there must be no rails in the streets and because traffic is continually moving. There are no hold-ups, no vehicles stop except the vehicle which it is desired to stop, and it stops at the curb. Their ever-increasing suburban population is cared for by placing their street cars underground, so that practically the only people who use street-car transportation are those who come from long distances. The minute these cars come into a congested district they are put underground where they can proceed without interruption and thus permit the traffic on the streets to proceed without interruption. That is the principal reason we can say that, by the law of the survival of the fittest, the automobile must of necessity drive the street car off the streets and that motor-driven vehicles must be provided to take its place.

Almost all growing cities are hampered in their development because the street-car systems have to make expensive extensions involving large outlays of capital to reach out and care for the outlying districts. Population is concentrated and the natural expansion of the city is prevented, resulting in extremely high rentals in the center of the city and relatively cheap land just a short distance outside. Street-railway systems have reached the point where they cannot compete successfully with the automobile, to the extent of making their extensions and getting franchises which enable them to operate at a profit. The result is that there is practically no extension of street-car lines. If they raise their fares they become less and less competitors of the automobile, because the automobile then more keenly cuts into their traffic. They are not measuring up to the needs of the cities and I venture to make the prediction that never again will street-car companies be able to operate at a profit and give satisfactory service on crowded streets in thriving communities.

We formerly heard about the efficiency of rail transportation. We had single-track lines and then, as more traffic came upon them, the speed was reduced and they became inefficient because one car could not pass another coming in the opposite direction. One car had to go off to one side and wait while another came down the line. Then, as congestion became greater, they put in two tracks so that cars could pass without interfering with one another. As more and more traffic went over the streets, when one car wanted to stop it did not stop the cars coming from the other direction, but it did stop the cars coming behind it. That is the condition we find today. Now that traffic is so much more congested, we must see to it that a vehicle does not stop a vehicle coming in either direction. In other words, we have to get away from line transportation and take advantage of the whole surface. That means the motor truck; and nothing can stop the transition to this from the two-rail street-car traffic on the street, because every economic need of the city demands it, and the service which must be given can be given only by the motor-driven vehicle. The street car still has one advantage over the ordinary form of automobile for this service, and that is its size. With a smaller number of people in the vehicle the operating expense of a driver and conductor is, of course, greater per person. The problem which engineers must work out to accomplish the introduction of the motor bus on the streets is to design passenger-carrying vehicles of larger capacity than those which are now common.

I think it would even pay in many cities if the street-car companies themselves would take their cars off the streets and substitute motor buses, still using their organization and terminal facilities. They would be able to make extensions and get the traffic which is now going to the automobile. In many cases their power equipments are now inadequate. They could well utilize all the power they are making for the necessary extensions of light and power for the community to take up all the surplus which they would have when the street cars are taken off.

In regard to interurban traffic, what advantage has the motor bus over the street car? Naturally, so far as speed and congestion are concerned, the same crying need of a change does not apply. But there again we have the necessity of going to a large capital expenditure for roadbeds and tracks, and it is difficult to see how that money can be raised, and how it is justified by the relatively small amount of passenger service. The result is that in many cases they do not expand and, because there is no adequate transportation, part of the country is not built up anywhere near as fast as it would have been had there been a transportation system for it. The motor vehicle can accomplish this. It can go outside the city; it does not need a perfect roadbed; it can operate over many roads as they now exist, while the street car cannot. Automobiles can go out and pick up the traffic at a profit. When they begin running over the line and transportation is established, more people go to live along it because they have some means of getting back and forth. The business builds up by taking the population to the places where the motor truck first went. There is first no need of transportation, because there are no people; but the motor bus goes out and supplies transportation, and people follow. That creates the demand and the volume of business which makes an ever-increasing number of motor buses necessary. As more and more people go out, and become more and more scattered, longer hauls and more and more transportation are required, not only to take people back and forth but to get their supplies to them.

We often hear that the cost of transportation is much higher outside than it is inside a city. People talk about the five-cent fare in the city and add ten, fifteen or twenty cents to go outside on the motor bus, but they do not stop to realize that it is because the street cars and the transportation are good only in the city that rents are very high, and the cost of living is on that account very high in the city. The extra cost of fifteen or twenty cents which they pay for transportation by a motor bus, is more than equalized by the better living conditions obtained for lower rents when they go out further. While they are actually paying more for transportation, they are more than saving it somewhere else.

The Pneumatic-Tired Truck

As to the possibilities of the pneumatic-tired truck for combined railroad and truck haulage, and of the long-distance truck to replace traffic now handled entirely by the railroads, I think that it is along these lines that the greatest future for the motor truck lies. This is possibly not because it will mean so many more trucks in numbers, but because the volume of the truck business depends upon tons per mile carried. Larger loads and the longer distances make possible an enormous increase

in the volume of the motor truck business. The use of the motor truck for such service as this is limited to very narrow fields when we use solid tires, because we cannot get the speed or the carrying capacity that we can get with pneumatic tires. To take care of this service successfully, we must use much larger units. We have used the 3 and 5-ton truck, and are now in the stage where we are rapidly changing over to pneumatic equipment on 3-ton sizes. What shall we do when we go above this? It was largely to find out what to do that we started the Akron-to-Boston Express, somewhat in advance of its economic practicability, to try to overshoot the mark rather than to grow up by easy stages; to find out quickly by actual experience what the weaknesses were, and how to overcome them. We learned several things. Incidentally we found it one of the best tire-testing experiments we ever made. We learned also that while it is not particularly difficult to make 12, possibly 15, perhaps 20-in. tires, it is probably questionable whether they are the tires to make for this kind of service. There is a certain limit to the outside diameter of a tire with reference to its cross-section. We began to find out when we got up to 10 and 12-ton trucks that we might possibly have to load them from second-story windows, because the center of gravity and the truck body were so high that we could not keep down to proper proportions for ordinary service. So we figured on what to do to offset that condition; to keep the center of gravity and the truck body lower. It seemed logical that the only thing to be done was to use multiple wheels.

It is just as foolish to try insistently to increase carrying capacity on four wheels in an automobile, as it is to attempt to do so on a railroad coach. The little four-wheel railroad cars in Europe have practically never gone above 10 tons' capacity, while by multiplying the number of wheels we build our own freight cars up to 50 tons' capacity. The same thing is true for the motor truck. I think we will find that the solution of the problem of the practical pneumatic-tired truck above 3 tons is to use multiple wheels, that is more than four, say six wheels. We finally had to experiment and build trucks ourselves. We are quite satisfied that the truck must be on tandem wheels and not on twin tires on the same wheel. The riding quality and carrying conditions will be better; and we will get better traction. By putting the extra wheels underneath the rear end of the truck body, we can avoid that damage to tires which we get with large single tires, because the tires are twisted and distorted with a big body overhang. We also get additional traction with a four-wheel drive. While the particular design or method may vary, we wish to express the belief that the motor truck with multiple wheels is the thing with which to accomplish the building of the larger vehicle, to replace street cars in the cities and for long-distance hauling to replace freight cars.

The average mileage limit of a freight car is something like 20 per day. That is because, when one freight car is loaded, it cannot move; it stands around and is shoved around waiting for another. When those two get together, they have to wait for another. The service is very slow and not economical. By the introduction of motor service by truck, the unit is due to move when the load is ready to move; it then goes to its destination. The same principle that applies to city traffic, of everything being congested and one car stopping everything else, is what we have in freight service today. Each car is dependent on many others and cannot move until all are ready. The motor truck in that respect will give service, because each truck moves when it is ready and is not stopped or handicapped by the action of any others. We have seen the great part played by the motor truck in transport during the war. It would have been almost impossible to supply properly the armies at the front by the railroad systems, and it was the availability and the quick multiplication of service by motor truck which accomplished the desired result of keeping the Allied armies supplied as they advanced.

Canada, South America and the Orient

Looking toward reconstruction, we know that the railroad systems of Europe are a network and that in the most sparsely-populated countries, South America, Canada and the Orient, there are no railroads. These countries have great natural resources. The European countries have very limited natural resources, based upon their population. The first-mentioned countries have been held back for years because they could not secure the capital necessary to put in railroads, on account of their sparser population. We know that, having roads and automobiles, it is not necessary to go to large capital outlay to provide transportation, and these newer countries will be very greatly benefited by the development of the automobile for passenger and freight carrying, for they can thus acquire the means of transportation. Combined with their natural resources, those countries have a distinct advantage over the European countries. They have built up and supported the European countries because Europe's transportation systems were so far advanced that it could manufacture and ship more economically than those countries which actually had the natural resources and the raw materials. The result was that the raw materials went to Europe and came back in the form of finished product. Now the sparsely settled countries are better able, through the automobile, to take care of their own finished products; and they will develop rapidly.

The introduction of the automobile truck and passenger car has reduced to a very large extent the values of the railroads. Their values were a combination of the cost of construction of their facilities, plus a franchise value given them because they had no competition. The introduction of the automobile, giving them real competition and substituting for their form of transportation a better one, has depreciated those franchise values. That is one of the reasons for the difficulty of further railroad financing, and why it will be easier to finance advances in automobile transportation. The peoples of Europe will find this fundamental condition to mean that they cannot go back where they were before, to their previous position of influence, because it will be taken from them by the newer countries on account of their ability to provide for themselves an adequate transportation system, which they could not do before. The tropical countries, for instance, where the population is largest and the natural resources greatest, have this chance, combined with the advantage they have recently gained by the elimination of tropical diseases, such as yellow fever, making it safe for engineers and men of the white race to go there and introduce transportation systems.

It is stated that about 7 per cent of the workers of the United States are employed in transportation and that in China about 50 per cent are so employed. This is because China is deficient in roads and railroads, so that half of the workers must be continually wheeling and carrying things about. According to this, China's poverty is largely due to this necessity for employing a large part

of the population in moving produce from place to place. Before China can enjoy a prosperity equal to that of the rest of the world, a great mileage of roads and railroads must be built. At present nearly all Chinese roads are mere foot-paths used by men with wheel-barrows and donkeys. The cost of haulage by this method, even with wages at 15 cents per day, is from 4 to 12 cents per ton-mile. That gives an idea why China is so backward in modern civilization, and of what can be accomplished in China, with her 400,000,000 people, by the building of good roads and supplying motor transportation. China has not had railroads because it was too expensive to build them, on account of the enormous outlay necessary for the rails. But, they can build roads in small amounts at a time, operate vehicles over them and consistently expand them. The same conditions exist in other places. I think that the war has set such countries fifty years ahead relatively, because capital can be and will be invested in road development there; they will have facilities they were unable to get before. They are the people who are most solvent and can command capital to come to them, because their credit will be best.

Roads and Tires

One other point in regard to the advantages of pneumatic over solid tires in motor transportation. The highways will be public property; they will not be built by private corporations and franchises given in order to encourage private capital to invest in them, as has been necessary in the case of the railroads. They will be built by public capital, but we will find that the cost of the roads will more and more be paid for by the traffic which goes over them, in the form of vehicle taxes which will probably be progressively increased. The initial cost and the upkeep of the roads will vary directly with the loads to be carried and the damage done by the trucks going over them. Suppose two loads are to be carried on 5-ton trucks, one on pneumatic tires and one on solid tires. We know well the difference in the kind of road required to stand up under the solid-tire traffic as against that of pneumatic-tire traffic, and we also know the upkeep cost for the two kinds of traffic. With the heavy motor truck developed on pneumatic tires, it will not take half the expenditure for good roads that it would if those trucks were equipped with solid tires. In other words, the same appropriation would build twice as many roads of a suitable character to carry pneumatic-tired trucks, as to carry solid-tired trucks. And, in the long run, the truck which damages the road most will be taxed in almost direct proportion. I think that the action of the State of New Jersey a year ago is merely a forerunner of what must be expected almost universally. This will make it necessary to substitute the pneumatic for the solid tire on all large trucks.

Two years ago we spent most of our time trying to convince people that pneumatic truck tires have merit, that there is some use for them. We are now trying to increase our facilities enough to produce sufficient tires of this type to take care of the demand which has been created. I think that truck designers will find that the pneumatic tire has sold itself on its merits to the public, and that they will have difficulty in designing trucks for pneumatic tires fast enough to take care of the needs and demands of the people. Any truck manufacturer who tries to influence public opinion and build his product along solid-tire lines will find himself in exactly the same position as were the men who said that the automobile would never amount to much. I think that we cannot do anything more valuable to meet the needs of the country today than to forget the design and scrap the material provided for trucks on solid tires if necessary, and devote our energies to the proper designing of a pneumatic-tired truck with the idea that it will be equipped with pneumatic tires only. It appears to us that the volume of business in pneumatic-tired trucks will be many times what it is today in pneumatic-tired passenger vehicles, and our whole development is based upon this. Personally, I think the only limit to the development of the pneumatic-tired truck is the amount of crude rubber and long staple cotton that is available to make the tires.

ADDRESS OF F. A. SEIBERLING

THE greatest and most vital industry in our country is that of agriculture. Allied with it and next in importance is that of transportation. For seventy years the railroad was the dominant factor in the needs of transportation in our country, but in the past twenty years there has come the motor-driven truck, which is now in process of evolution, and which in my judgment will result in a revolution in the transportation of the world's goods. It is less than twenty years ago that we made the first pneumatic tire. We started twenty-one years ago to make bicycle tires and solid carriage tires; very shortly thereafter we commenced making pneumatic tires for small runabouts. The type then produced was the single-tube tire, with little studs in the base fastened by bolts at four points through the rim. It served very well on light vehicles. Then came the electric motor buses, first appearing in New York on Fifth Avenue. The best tire that could be devised for them was that same single-tube pneumatic with the four studs through the base of the rim, held by plates in the base of the tire. It would take a long story to relate the difficulties we and other manufacturers suffered in the effort to put pneumatic tires on these motor buses. They were an utter failure. Out of it, however, came the natural evolution through the pneumatic tire with the inner tube, until we arrived at the state we are now in. We demonstrated that we could carry considerable weight on pneumatic tires with single inner tubes, but there was a limitation largely due to weight and speed.

When we began to develop cord tires, we were dealing with a new principle of construction; we have more than doubled the weight-carrying capacity, with higher speed and less heat. We realized five years ago the evolution that is now under way. Some of us believed, and still believe, that the ultimate tire is the cord tire and that there will be no fabric tire, much less any solid tires on moving vehicles. We believe that so firmly that most of our engineering force is employed on the development of the cord tire.

The world views the development of the motor vehicle and the tires that have come along with it in the past twenty years as a marvelous thing; it has been. No page of history has been brighter in mechanics than the progress in automobile manufacturing in the last twenty years, but I still believe we are largely in our infancy in the matter of transportation. When I make that statement I must connect with it development other than the developments you will make and developments we will make, because they are largely traveling parallel. I must take into consideration what I believe is coming in the development of our highway systems.

Future Highways

We have over 2,000,000 miles of roads in this country. We are commencing to dignify them with a higher term, highways. Out of those 2,000,000 miles, less than 200,000 are what can be called improved. Such improvement as they have will be called negligible ten years from now. They are inadequate. The development of the motor truck is away beyond them. We must get a new vision of the highways. That vision will carry us to the highway with a solid foundation and hard surface; one adequate to carry at least a 5-ton per wheel load for truck service, and wide enough for the traffic of high-speed vehicles without danger. We will have no more 12, 14 or 18-foot highways, except in sparsely-settled districts. We are surely coming to the solid-foundation road, adequately drained.

It appears to me that you who have the destiny of motor-truck development largely in your hands must see the future; you must have the vision of the final thing, as near as you can get it. It would be a simple thing for you to design the ultimate car if you knew that ten years from now every highway built in the United States would be solid, substantial and smooth, and that you could put under it tires that would carry any load you would give it. I am referring now to the pneumatic tire. If you knew all that, you would design a truck or a car entirely different from the ones you now design. In my judgment we are working to that end with certainty.

Progress in Design

One of our engineers brought in the design of a six-wheel truck, the ultimate truck, along that line. I of course laughed inwardly, but I let him talk. He took me out on the hills one day over our rough roads with this truck and I was utterly dazed at the way it operated. I saw in that idea a start that meant less weight in the truck, less cost and higher service; largely as a result of the development of the pneumatic cord tire. The compensation of the leverages of the turning mechanism, the fifth wheel, etc., is largely provided in the swing of the pneumatic tire.

We spend hundreds of thousands of dollars experimentally, and a majority of it is wasted, but now and then we get something that is worth all that we have wasted ten times over. You inventors and designers know that the progress of the world has been made only along that line and that it must be done. When you have developed something entirely new, you have achieved something. You have rendered a new service to mankind, and that is the great joy of men who are doing constructive things and making progress.

Possibilities in China

In China there are 400,000,000 people; it is a country larger than this country and has a railroad mileage of 1 to 30 of ours and a motor-car service that is negligible, almost confined to the cities of Shanghai and Hong Kong, some 5000 or 6000 cars. Think of that tremendous gap that can be filled and will be filled sometime. Roadways are so narrow that a vehicle could not get through many of them; railroads are almost impossible to build because of Chinese traditions and reverence for the dead. So many have died in China in the centuries before us that nearly every ten square feet contains a grave, and they do not allow railroads to be built over graves. That difficulty of overcoming the prejudice of a people is an enormous one, and it will take centuries to overcome it in China. But they have thousands of miles of post roads, some of them built by the Manchus centuries ago, paved with blocks of stone 3 to 5 ft. long and 10 to 12 in. thick. They are largely in disuse. Time has covered them and they are worn to some extent, but it struck me immediately that there is the foundation for a good road. With a surface of the kind we could build, with drainage systems along the side, we could make a good road at nominal cost, for labor in China is very cheap.

None of us has visualized China for automobiles or automobile tires, but I believe that within our lives we will find motor cars running over Chinese roads. We will find that that great mass of people will some day awaken by virtue of American and European enterprise and start road-building in good solid fashion. When they build a road from Tientsin to Pekin as an experiment in a hard-surface road, motor cars will be there the moment it is built, and we will have a new market. After that has been done, other roads will be built and the post roads will furnish the means of transportation that they have been thinking of as applicable only to railroads. I think it is going to be very difficult to get money for suitable railroads in China. This will not be necessary if they build roads there suitable for motor cars such as we have in this country.

Predicted Exit of Solid Tire

We look to you S. A. E. members to work along with us in building the ideal truck for the service of this country. We are thoroughly convinced that three years from now the solid tire will be dead as applied to truck service. We believe that the cord tire we are now making is only the starting point of the finished product that will be in use five years from now. We are refining and improving all the while, doing everything we can to meet the situation. We believe we will make progress. Forget the solid tire and think only of the pneumatic as adequate to every need, for it will carry the heaviest loads as well as the lightest, and carry the high-speed trucks which the hard tire cannot. The solid tire is almost as bad as the iron tire in destroying the roads. The pneumatic tire absorbs all the shocks.

Report of Constitution Committee

THE Constitution Committee of the Society, whose duty it is to consider and make recommendations on all proposed amendments of the Constitution, has made the report given below, in connection with the constitutional amendments proposed at the last meeting of the Society, as set forth in the January and April issues of THE JOURNAL. This report was approved by the Council of the Society at its meeting held on April 9, 1920.

THE REPORT

Careful consideration was given to the report of discussion had at the meeting of the Society, held Jan. 7, 1920, covering the proposed changes. In addition, letters from various individuals bearing on these questions were read and comments analyzed.

As a result the following suggestions were made:

C 8 should read as originally outlined in the Constitution. In other words, no change in the age limit indicated is desired. The particular reason for this is that it was the opinion of the members present that there were many individuals in the automotive industry, in fact, it might be said the great majority, who possessed the fullest qualifications for membership, and who are under the age of 32. This is probably more applicable in the automotive industry than in any other field of engineering activity, and it would be a hardship and an unfairness to not honor a deserving applicant by full membership in the Society.

Under C 10, the age limit of 26 years is recommended to be changed to 30 years, reading as follows:

"....who at the time of election are under 30 years of age, etc."

In addition, the second sentence of C 10 should read as follows:

"A Junior member may upon reaching the age of 28 and shall upon reaching the age of 30, etc."

In connection with these changes it is realized that many arguments in favor of the various age limits mentioned by different individuals exist. While these will not be reviewed, it is suggested that the proposed change is more or less in the nature of a compromise, and should meet nearer with the approval of the majority than any of the others which have been suggested.

It should be noted in connection with the foregoing changes that the dues for membership will always be those applying at the time of admission, except as may be modified by amendments later submitted. In other words, a Junior, for illustration, always pays an annual fee of $5.

Under C 29, a modification has been made, and the necessity for which is brought about by the rapidly extending field of activities of the S. A. E. Realizing the manner in which the Council is chosen, full consideration being given to the type of individuals proposed, it is believed that this paragraph should read as follows:

"The affairs of the Society shall be managed by a board of fifteen directors chosen from among its Members or Honorary Members, which shall be styled 'The Council.' The Council shall be chosen from among members who have demonstrated by effective work as members of Society or Section Committees, or otherwise, both willingness and fitness to devote time and energy to the accomplishment of Society work. The Council shall consist of the President, the First Vice-President, and five Second Vice-Presidents, six Councilors, the Treasurer, and the surviving Past-President who last held office. The five Second Vice-Presidents shall preferably be chosen to represent respectively motor-car, aviation, tractor, marine, and stationary internal-combustion engineering."

Note is to be made that the last portion of the recently proposed C 29 has been omitted, and this for more or less obvious reasons. If in the opinion of those empowered to choose there is no representative in a particular field capable of properly representing the Society, elimination of such a representative from the Council in this manner may cause a great deal of unfortunate feeling. As a matter of fact, it is believed that all of the industries now represented are sufficiently big to make it a simple matter to select some individual who is fully up to the qualifications required.

Should a representative be chosen and be found wanting in any particular, his detrimental effect upon Society activities will be, it is believed, much less than would be the case were the entire field of industry represented by him ignored.

Constitution Committee:

(Signed) D. L. GALLUP, Chairman.
" W. G. WALL.
" EDWARD ORTON, JR.

NEW RADIO TRUCKS WILL SOON BE GIVEN TRIALS

THE radio trucks to be used by the Air Service are patterned after the models used by the British. The body is totally enclosed and is 120 in. long, 64 in. wide and 64 in. high with a door on the right side and two glass windows provided with canvas flaps. Room is provided for three operators and one squadron radio officer. One bench supports a type SCR-67A ground radio telephone set, one type SCR-54A crystal detector receiving set and one type SCR-121 low frequency amplifier. Storage batteries are held in clamps underneath the bench. A type SCR-79A continuous-wave radio telegraph transmitting and receiving set is installed on another bench. A desk for the officer is installed with a battery compartment underneath. A 6-volt circuit, comprising two lamps, is connected to the storage batteries, while a 110-volt two-lamp circuit may be used when a suitable external supply is available. External brackets are provided for carrying antenna masts. Each set is provided with its own antenna. No fixed permanent antenna is provided for a station, to be set up at the truck.

The ground radio telephone set will be replaced with a higher powered telephone set, which will increase two-way telephone communication to a distance of approximately 50 miles. These higher powered sets are not available at the present time. The radio telephone set will have a transmitting range of approximately 15 miles under ordinary conditions for work from ground to plane and vice versa. The transmitting range of the continuous-wave set is in the neighborhood of 50 miles. The receiving ranges of these sets will depend upon the local conditions and mainly upon the power of the transmitting set at a distant station whose signals are being received by that on the truck.—Air Service News Letter.

Addresses at the New York Aeronautic Meeting

THE Aeronautic Meeting of the Society which was held in New York City on March 10 was concluded by a dinner at the Hotel Astor. The speakers were President Vincent, who talked on general development of aeronautics with particular reference to the Air Mail Service; Major-General C. T. Menoher, chief of the Air Service, who presented some interesting facts and figures as to the present status of military aeronautics and advocated the maintenance of separate Air Services for the Army and the Navy; Air Commodore L. E. O. Charlton, formerly military attaché of the British Air Service; Col. Thurman H. Bane, chief of the Engineering Division, Air Service, who pointed out that a National Defense Department could very well care for the operation and maintenance of all Government aircraft and spoke very hopefully regarding the anticipated use of aircraft on a large scale; Past Vice-president George H. Houston, who traced the development of commercial air flight in America and emphasized the necessity of the Government maintaining a properly equipped organization for testing out new designs and doing whatever is necessary to establish the science of aerodynamics on a sound basis, the actual designing being undertaken by civilian organizations; and Major Maurice Connolly who, stated that the aircraft sales departments could do much to facilitate the establishment of needed landing fields by presenting concrete statements of the amount of expected business.

ADDRESS OF PRESIDENT J. G. VINCENT

I AM more than ever convinced that our membership as a whole does not thoroughly appreciate either its opportunities or responsibilities. In 1911 we were all proud of our Society and its success, but I doubt if many of us realize that we then had only about 600 members. The membership has since increased rapidly, in a constantly upward curve; in 1912 it had passed the thousand mark; in 1913 it reached 1500; and at the beginning of the great war it was about 2000. It hardly seems possible that the Society was relatively so small at that time. Its continued steady growth, its ever-increasing activities and its greater and greater professional and financial success during the war are well worthy of note. We all know that the reason is the essentially important character of the automotive industry and its engineers.

In 1918 there were about 3000 members and in 1919 approximately 4000. The curve is tending in a very satisfactory direction and we now have well over 4500 members. These figures include individuals, companies and their representatives and enrolled students. High-grade representative members are being constantly added and our officers are frequently surprised at the number and character of applications received and the possibilities of additional high-grade membership which are constantly developing. This is a picture that we can all be proud of, but let us not forget that this membership comes about through added activities, each in turn carrying with it tremendously important new responsibilities. It is constantly borne in upon us that we are in the midst of greater and greater things.

The present basic status of the Nation economically and financially is much involved. In explanation of current conditions, one authority states the following reasons in the order of their importance:

(1) Increased volume of money and credits
(2) Wide increase in wages due partially to war necessities and Government wage scales
(3) Lessened world production
(4) Increased cost of production
(5) Reckless extravagance and a spirit of speculation
(6) Profiteering

However favorably we in the automotive industry may be situated as compared with those in other industries, we cannot ignore the plain facts of the general condition. The S. A. E. must go forward with increasing vigor, intelligence and effectiveness. It is a grave mistake to think that the business man can find no useful place in the Society. On the contrary it has been shown clearly that in the standardization work the business man has conspicuously accelerated proper and useful action. The different classes of members working together accomplish very desirable and beneficial things that would otherwise be missed.

The Function of the Society

The basic function of the Society is to reduce costs to the producer and to the consumer and make feasible better products. It has made a record as an engineering organization second to none. The world has seen no more admirable and effective example of cooperation than that of the automotive engineers. It was their cooperative effort instituted fifteen years ago that placed the American automobile in its high rank among the products of the world. The standardization achievements of these men have been based on thorough study, merit and common sense from the start. Greater economy and speed of production of high-class automotive vehicles of many kinds now well known have resulted from their broad and intelligent procedure. The specific things done to this end are too numerous to mention.

The modern use of automobiles and much other automotive apparatus would not be possible if the far-sighted automotive engineers had not promulgated and reduced to almost universal practice many standards. The Society has established nearly 300 distinct mechanical and material standard specifications, of mounting dimensions, accessories and the like, and the work has only begun. The American automotive engineers have been the progenitors of the world-wide standardization movement now very plainly recognized. Standardization is a wise simplification of details and is vitally important to international trade. This is appreciated keenly by those manufacturing countries throughout the world now striving to control the key industries.

With such a splendid record of achievement during the war, the Society is now hard at work on many pressing problems. How are aircraft production facilities to be utilized commercially? How is the problem of the more efficient use of fuel to be met to conserve the limited supply? How is the need for a greater and ever-increasing supply of food to be faced in view of the shortage of

labor? How is the distribution of food and other commodities, to communities distant from the railroads, to be accomplished? How can automotive engineers contribute to the successful solution of these problems so that this country shall become the successful competitor it should be in the markets of the world? How can lighter, more efficient and less expensive automotive apparatus be produced?

These are all questions in which the automotive engineer has a vital interest and which he must answer; there are many others of like nature. The stimulation of research in new fields will have no small bearing in contributing to the desired results. These are exactly the things for which the Society stands. Many of them will be treated at the approaching Summer Meeting. The Society fully appreciates the need of bringing about a solution of the problems mentioned and others of like nature.

We are all keenly interested in the development of aeronautics because it is of vital interest to our country, forming as it does the basis of preparedness in the air. I think everyone will agree that we must never again allow this country to get into the relative position it occupied in aeronautics in the early part of 1917. The solution of these problems very largely depends upon the automotive engineers, but we must take care that we analyze the problems step by step and make sure of our recommendations. To carry on this work intelligently, we must keep constantly in touch with every phase of the situation. I personally believe that the final answer to thorough preparedness in the air lies in commercial aviation, but at best it will be some time before aviation can be put upon a commercial basis. In the meantime we must very largely depend upon Government activities to keep us prepared and as automotive engineers we should give maximum cooperation to Government officials to help them obtain the greatest possible value for every dollar spent on aviation, as measured in terms of preparedness. Our cooperation will be of direct value in proportion to how well we are posted and how well we understand the problems faced by Government aircraft officials. Thorough cooperation can be brought about only by a complete understanding of each others' problems. The only way to learn each others' problems is to become well acquainted and discuss the situation frankly without regard to personal interests.

Aerial Mail Service

I shall discuss briefly the possibilities of our aerial mail service from an engineering and production point of view. What we all desire is to be reasonably well prepared in the air for possible emergencies. What is the best way to accomplish this result? Anything that will promote the use of airplanes and thereby develop the art and make airplanes available, will be along the right lines. During the next few years, at least, such development must be brought about under Government direction and with Government funds to a large extent. The Government must therefore determine the best way to bring this development about. We all know that the most effective way to bring about a development is to have a real use for the article which is to be developed, and the Government has such a use for airplanes in the aerial mail service. Why not develop this service in a whole-hearted manner and bring about the results that will be bound to occur, if it is taken seriously and properly extended throughout our country? Such a course of procedure would, in my opinion, bring about the following results:

(1) Airplanes of greatly increased reliability would be evolved, because the planes must fly on schedule time and failure would therefore be brought forcefully to the attention of the proper authorities

(2) Airplanes of greater cruising radius would be evolved, as it is desirable to fly for long distances without landing

(3) The cost of airplanes would be gradually brought down to a proper level, because manufacturers would receive sufficient orders to warrant tooling up

(4) Economical reliable air craft engines would be developed and as the quantities required would permit of tooling up, it naturally follows that such engines would be obtainable on short notice at minimum cost. Contrary to popular opinion, these engines could be developed so that they would be equally good for the mail service and for military purposes. Such a development would be of paramount importance, because it takes at least one year to develop an airplane engine and get it into production even under war-time pressure, while the airplane itself can be designed and put into production in less than one-third this time, provided its engine is a known quantity

(5) Many improved instruments for airplanes would be developed, including such important ones as are required for night flying, flying in cloudy weather, etc.

(6) Such a program would gradually increase technical knowledge and develop craftsmen, so that in case of any emergency material for a war-time aircraft organization would be immediately available, instead of losing much technical knowledge and many expert artisans developed during the war, as is now rapidly taking place

(7) There would be a constant demand for good, reliable pilots, so that we would always have a large number of them in training, immediately available in case of an emergency

(8) Such a program, by keeping the aircraft industry alive, would promote the development of commercial aeronautics; thus, in turn, would not only hasten the development of the aerial mail service but, what is more important, make available much added technical knowledge and helpful manufacturing facilities for use in case of an emergency

(9) A complete system of good landing fields throughout our country is probably the most important step required to make the development of commercial aeronautics possible. Obviously, the Government cannot be expected to build or maintain such fields, but the expansion of the aerial mail service would, in my opinion, bring about the desired result. These landing fields should be provided by the cities to be served by the aerial mail. I can think of nothing that would stir up so much interest in commercial aeronautics as a system of landing fields throughout this country, with mail planes coming and going regularly every day

(10) In case of emergency, if such a program were in force, we would have a great number of airplanes and pilots quickly available to do very valuable service for the Army and to a certain extent for the Navy. It is of course true that the planes would not be military machines, but they could be so constructed, without interferring with their value as mail carriers, that with the addition of some armament which could be very quickly installed they would be very good for observation, photographing and bombing work

(11) A program of this kind would result in the maximum amount of activity and development at minimum cost to the Government, because this work must be done and, by using airplanes to do it, the revenue accruing from such operations would be applied toward the cost of equipment and maintenance

Experience to date indicates that the aerial mail service can be made almost if not entirely self-supporting after being established; but this should not be taken as too important a consideration, for, to bring about the results desired it will be important to have sufficient appropriations made to maintain experimental work constantly with a view to improving the equipment from month to month. After considerable thought, I realize more fully the possibilities of bringing about a wonderful development in aeronautics through the use of the aerial mail service as a vast proving organization. I feel sure that if such a program could be made a reality, there would be absolutely no question that the United States would lead the world in aeronautics within a very few years.

When we entered the recent war the Government had no trouble in obtaining prompt delivery of passenger cars and trucks, solely because such vehicles had been thoroughly developed and were in quantity production for other uses. The aerial mail service offers a possibility of bringing about the same condition in aeronautics, by making mail-carrying airplanes and pilots immediately available in cases of emergency and by bringing about the commercial use of airplanes.

ADDRESS OF MAJOR-GENERAL C. T. MENOHER

I SHALL present a few facts as to the present status of military aeronautics in this country and a thought or two as to what we may develop for the next war of any magnitude. Due to the enforced development in aeronautics during the late war, the science has advanced as far as it would otherwise have advanced in fifty years. Practically all important and lasting progress made by the human race has been by a gradual process of evolution as distinguished from revolution. I regard the advance in the science of aeronautics during the war as in no sense revolutionary, but strictly evolutionary. A comparison of any one of our standard airplanes with the one in which the Wright brothers made their first flight will show that the evolution has been very gradual and along normal lines, the element of time only, that is ordinarily associated with the process of evolution, being in this case very materially shortened. Now that the war is ended and the world is returning to its normal state of being, we can look for a period of normal conservative development in the science of aeronautics.

From the lessons gained in the use of aircraft during the late war, we can anticipate in a measure the part it is likely to play in future wars. It is significant that the industry which produced the aircraft was strictly a development of the war. While it is possible to visualize the possibilities of aircraft, we cannot determine them definitely and can only hope that the industry to produce the aircraft needed for a future war will be in existence contemporaneously with the need. Whether it must be developed as a war-time measure, as was the case in the last war is dependent in large measure upon the success of commercial aeronautics. If aircraft in industrial and governmental usage is proved to be economically successful, the industry which produces the craft will be available for war production. There will be many types of aircraft in operation suitable for some war use and a great personnel having a large part of the necessary knowledge for their operation, which will be a distinct asset. In case, however, of the economic failure of aircraft, the tremendous expense involved in operating an adequate air fleet will necessarily limit the number which can be maintained as a preparation for war.

In future wars, the first arm of defense to come into active operation will be the air service. The relative size of our air force and that of the enemy, and the total number of machines that it will be possible to put into operation immediately after the war begins will determine the character of the preliminary phase of the war. It is entirely possible that one belligerent may have sufficient aircraft of adequate size and range of action to drop enough explosive and deadly gases on the centers of government, production and military strength, to end the war almost before it has begun. Certainly it would be possible to hamper and delay the embarkation and transportation of any expeditionary force long enough to enable the aggressive belligerent to make a considerable preparation. In this connection it should be remembered that the sea, which was formerly a barrier, has now become a highway; and that we will have much less time than formerly in which to prepare to resist an invasion. The advent of aircraft has very materially shortened this time.

Since we cannot determine definitely whether commercial aeronautics on a large scale will be successful, and consequently cannot visualize the size of the industry in the future, it is impossible to anticipate the size of an air force that may be thrown against us by any first-class power. It is a military principle, however, to recognize that the initiative and resourcefulness of the enemy are probably as great as our own, and to plan and prepare for meeting the worst situation conceivable. We should keep in mind what might be our situation should aeronautics take the place in our governmental and industrial life that now seems possible, and that a possible enemy may have at his disposal a large air force and the industry necessary to maintain it. With comparatively little advance in the development of the lighter-than-air craft, we must be prepared to attack and destroy dirigibles capable of carrying enough explosives to paralyze our industrial and governmental centers. If we have an adequate air force at our disposal we should be able not only to retaliate but to attack an invading force at his ports of embarkation and to continue the attack on his transports and fleets until our Navy has joined with his. In the naval engagement aircraft will play an important part, not only as an auxiliary to the battleships themselves in fire control, but by actual attack by both heavier and lighter-than-air craft on hostile war vessels themselves. On the approach of the enemy fleet to our coastline, aircraft will cooperate with our coast defense; it will attack during his efforts to disembark and establish a base on our shores; it will cooperate with our land forces after the establishment of his base; and it will continue to attack his transports and ports of embarkation, and even his depots and munition plants, throughout the war.

The two general classes of use of aircraft in war are first, by the Army and Navy in direct cooperation with their troops or their fleet, including observation and reconnaissance, regulation of artillery fire and liaison work; and second, pursuit or the attack of aircraft by aircraft; bombardment, day and night, of ground objectives; and attack by machine-guns and small cannon of

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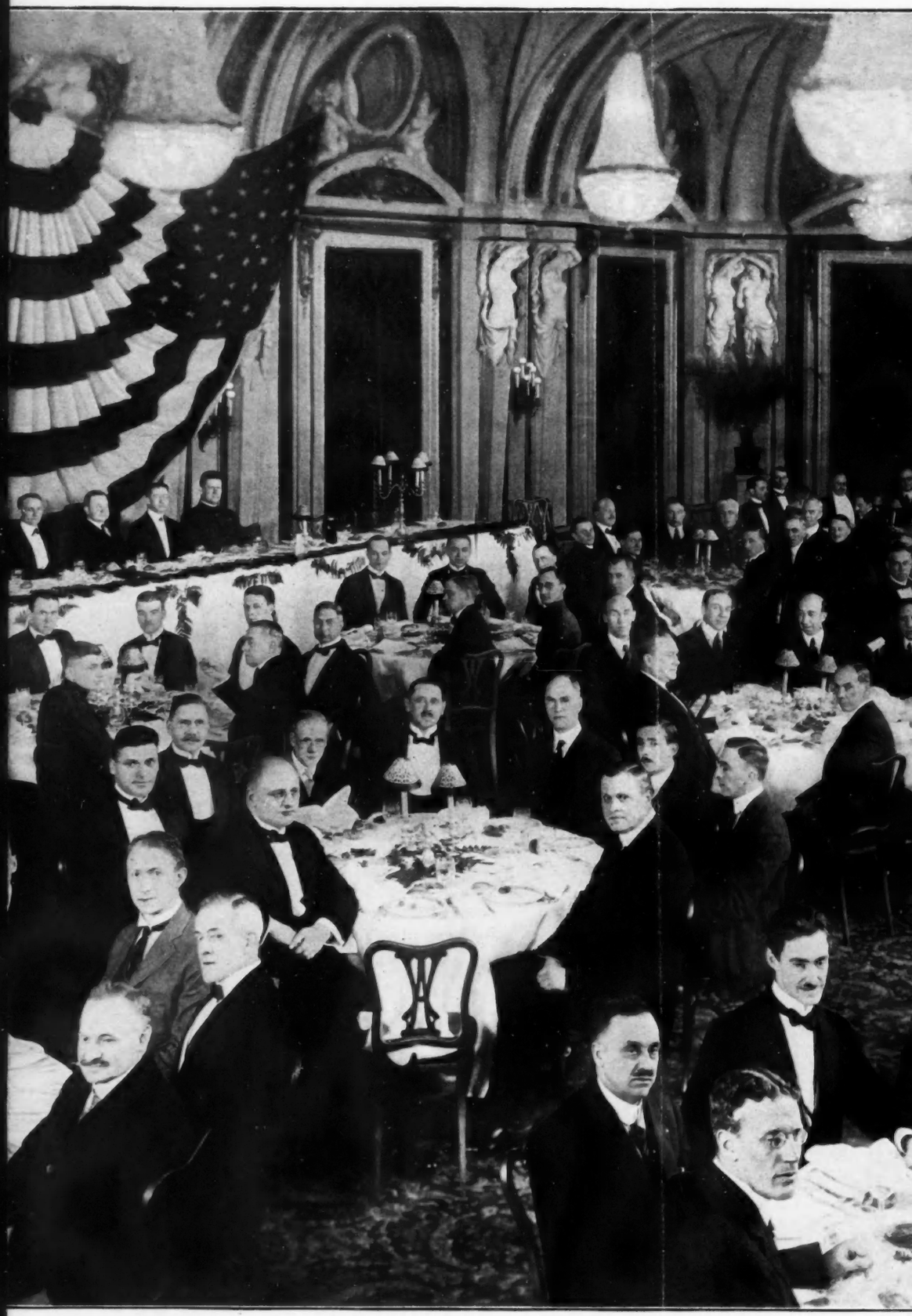

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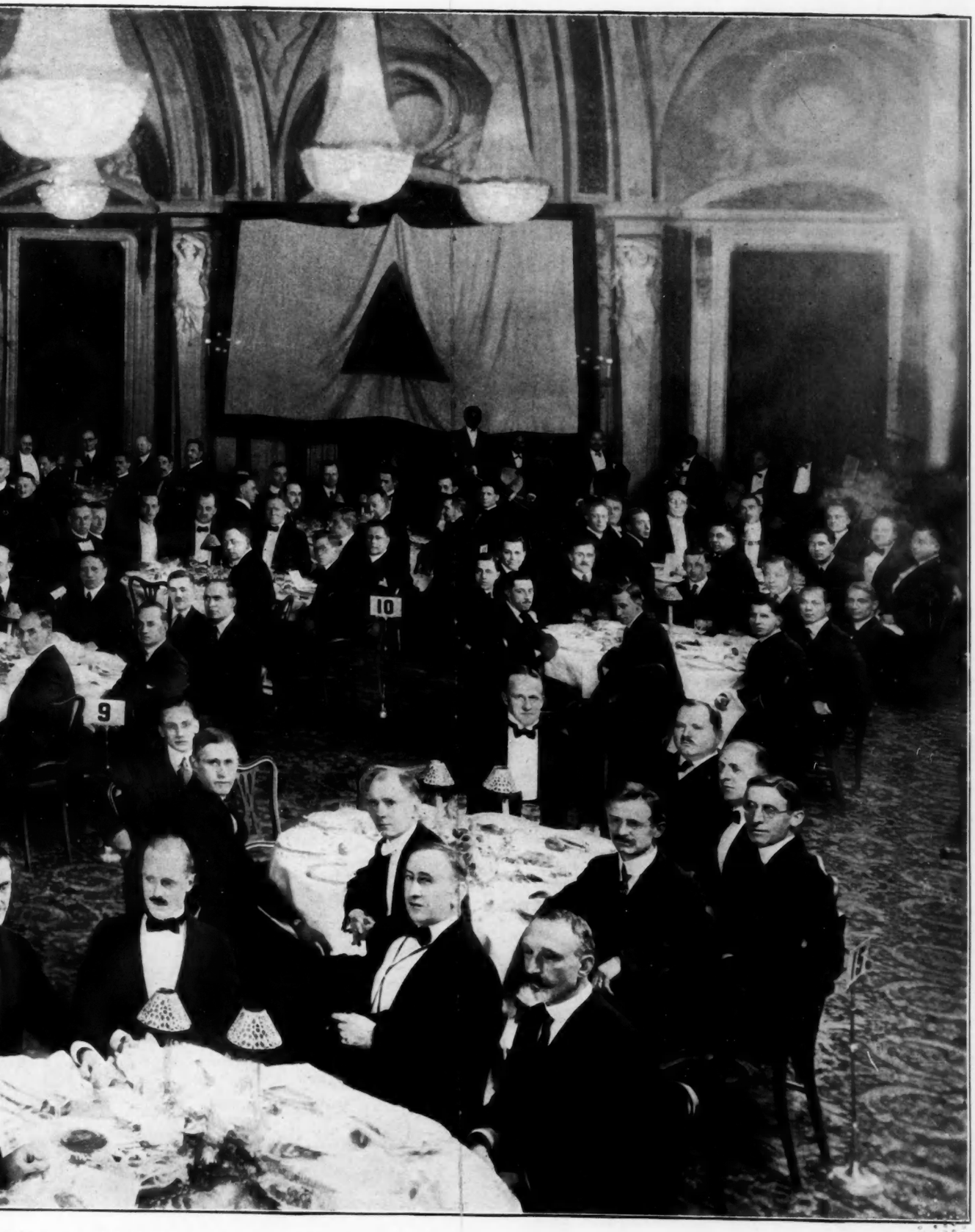

RONAUTIC DINNER OF THE SOCIETY WAS HELD ON MARCH 10

troops and material on the ground. The first class of use increases and decreases with the size of the Army and the Navy. The second is dependent only upon the ability of a nation to produce and maintain aircraft. The reliance of the service upon aircraft has become such that it will be necessary to maintain a considerable air force as a part of every peace-time establishment. It will be impossible to train troops and prepare them adequately for war without it. Every country must be willing to assume the expense involved in producing aircraft for the peace-time training of its Army and Navy, no matter what the expense may be; so, we can expect in any future war to find at the beginning of hostilities the aircraft needed for immediate service with the Army and Navy.

It will be impossible for any country, no matter how wealthy, to maintain an industry capable of turning out aircraft at the rate required unless commercial aeronautics is successful. In any case, when war is declared, there will be a determined effort on the part of the belligerents to produce aircraft for war purposes just as fast as possible, and the size and training of the then existing industry, which will form a nucleus for expansion, will probably determine which belligerent will be able to gain control of the air. Furthermore, it is almost inconceivable that control of the air will not be one of the deciding factors in any future war.

Future Tactical Use of Aircraft

In any war with a first-class power, the tactical use of aircraft against enemy elements coming across the sea, whether in the air or on the water, will probably proceed along the following or similar lines:

(1) Long-range reconnaissance by rigid airship from some shore base to locate hostile air forces or hostile fleets. This will lead to combat between airships

(2) After contact has been established between air forces, a battle or series of battles will occur between pursuit aircraft to determine the control of the air

(3) Control of the air having been established, aircraft will attack enemy ships, both surface and submarine. This will be by

(*a*) Direct attack. Attack aviation will engage ships of all characters with cannon and machine-guns, to occupy the personnel of the ships and prevent them from using their means of defense against aircraft. Such attacks will be carried out at low altitude and control will be by radio from the air, in addition to pre-arranged orders and ordinary signals

(*b*) Bombardment. When the attack aviation has engaged the hostile naval vessels, bombardment aviation will attack with projectiles of weights up to and probably exceeding one ton and designed to make direct hits on the vessels. Projectiles being considered for this purpose are thermite or burning types; those throwing smoke screens on the ship itself, to prevent the personnel from seeing objects around it; armor-piercing projectiles of various kinds, designed to penetrate protective decks; depth bombs, etc.

(*c*) Water torpedo attack. By bombardment airplanes carrying water torpedoes. This attack will be made under cover of the two attacks just described

(*d*) Submarine attack. Directed by radio from airplanes.

Attack at night will be carried out in a manner similar to that of the day attack, with the additional use of flaming projectiles and parachute flares to blind the personnel and put out their searchlights.

It is significant that at the price of about $35,000 per plane, a fleet of a thousand bombardment planes could be acquired for the present price of one battleship.

The Air Service Organization

Much has been said and written about the lack of a definite aeronautic program, but as a matter of fact the Army Air Service has had a definite program for a year. The putting into effect of an adequate organization came first, one that would handle our peace-time activities and at the same time be capable of expansion in case of war. Such an organization was adopted a year ago, and the opinion of the majority of air-service officers qualified to pass judgment is that it is fundamentally sound. This applies not only to the organization of the office of the director of air service, but to the organization outside of Washington. The administrative end of the organization having been settled upon and put into effect, the next step was to adopt and put into effect the organization of the air service proper, by which I mean the organization of the various tactical units, such as pilots' and mechanics' schools, and supply and repair depots. This has been accomplished in great part. In addition, provision has been made for aviation service on the Mexican border, in the Philippines, Hawaii and Panama, and for service with our coast defenses.

It should be borne in mind that this organization was effected when practically every enlisted man in service at the time of the armistice had to be discharged, as well as all officers except 149 regulars and 1200 emergency officers; the organization had to be entirely reconstructed. The Army air service has made various studies as to the needs of our Army and each of them has given practically the same results as to the number of officers, enlisted men, cadets, etc., to carry out the requirements of coast and insular defense, the squadrons for use with tactical divisions and the requirements of supply, maintenance, engineering and the maintenance of our pilots' and mechanics' schools. We have had also a very definite plan as to the number and types of planes needed to carry out the program. The only thing lacking has been congressional authorization and the necessary appropriation. It is true that we are at present reduced below the limit of efficient service in both officers and enlisted men, but we still hope to get some part of the additional personnel for which we have asked and we propose to carry on, doing the best we can with the means provided. I have profound faith in the future of aeronautics and I am willing to wait with patience for the outcome.

Separate Air Service

As to my attitude with regard to the so-called seperate air service, I have been contending all along for three things. First, the Army and the Navy should each retain its own air service; that is, the personnel and materiel necessary to carry on the work of the Army as a thoroughly balanced force, complete in all its parts, should be retained as a part of the Army. I consider that the taking away from the Army of the air-service personnel which is to function with the Army would be a very grave mistake. Too little cohesion existed between the ground troops and the air service during the war. I attribute this more to lack of intimate association than to anything else. The only way in which we can get mutual sympathy

and cooperation is by having these arms of the service closer together. Second, the Army and the Navy each have special requirements in aircraft that would not be appreciated by any purely civilian agency, and each must carry on its own experimental development to the end that the special requirements can be met. After having once determined upon a type suitable for a special need, the matter of production should be turned over to some other agency. Third, all matters of production should be in the hands of some central agency. It seems logical that this should be a civilian agency, either independent of or subordinate to any of the present executive departments of the Government. This agency, in addition to handling production, should take care of all the so-called civil activities of the Government. These include the forest patrol, the coast and geodetic survey, rules and regulations for the navigation of the air, the licensing of pilots, inspection of aircraft and all things that must be covered before we can have thorough Government control of civil and commercial aeronautics.

ADDRESS OF COMMANDER G. C. WESTERVELT

THE future of naval aeronautics is bound up in the future of aeronautical science in general. Along with military and commercial aeronautics, naval aeronautics must be pushed ahead as far as possible. Before commenting upon the expectations of the naval service with regard to aeronautics, it will be interesting to review several features of its development thus far.

The first twelve-cylinder Liberty engine to fly, flew in a Navy flying-boat. It was first shown at the Bureau of Standards in Washington. I was very much interested in it, because the Navy had decided to plunge absolutely on the Liberty engine. They had decided to install it on all of the flying-boats they were going to use for submarine patrolling purposes. At this time the Liberty engine was not an approved instrument; so we were watching it with the greatest interest.

The engine was made the basis of the Navy program. Its success was so great, although it had many defects which had afterwards to be worked out, that we decided no mistake had been made. The risk we had taken in plunging on one engine and basing our entire program absolutely on its successful outcome, had been warranted by the remarkable skill of the engineers who had designed it. The result was that when the Liberty engines began to come through in improved condition, we were able to ship flying-boats abroad for use at the fifteen stations we had in European waters, in such numbers that more than two months before the signing of the armistice we stopped shipping them. This was made possible by the fact that the Liberty engine was remarkably successful and because most of the pioneer aircraft manufacturers in the United States were assigned to Navy production exclusively. It demonstrated conclusively that the pioneers in the airplane business were the ones who knew most about the plane business, they being able to get more quickly into the comparatively small-scale production that the Navy needed.

Navy Plans for Aircraft

Our plans for the future are mainly plans of development. Naturally, we do not expect, during the next year or two, any considerable quantity of production. We do not need it. But what we must undertake is development work along strictly naval lines. It has very little bearing upon types required for land work; the Navy has problems to meet which are peculiar to its service.

At present, from what is probably a comparatively limited viewpoint, we do not see the need for any very great number of types. We are planning, during the coming year, to develop to as high a point of perfection as possible, a small single-seater machine for fighting purposes. This machine is to be carried on the turret of a battleship, or on board seaplane carriers. It is to be flown from the turret or from the deck of the ship and will have many characteristics similar to those of land fighting machines. If possible we would like to develop it as a seaplane, however, so that it could land on the water and the pilot ride in safety. Failing in this we will probably adopt a device developed by the British, having air-bags placed on the flying craft which are inflated just before landing. As a matter of fact, such devices are already employed on planes obtained from the army, but they are not entirely satisfactory; the planes are too heavy and the engines are not quite powerful enough.

The second type required is a machine for reconnaissance, gun spotting, the control of target firing and observation purposes to limited distances. It is not a machine that will present any great amount of difficulty. The main thing is to specify its characteristics correctly. It will not be a high-speed machine.

The third type is a seaplane for torpedo carrying. I say "seaplane" in connection with all of these machines because for flying over the water we want seaplanes, if possible, and such a development involves great difficulty. We have no engine of sufficient power to really do what we want to do. Until such an engine is developed we cannot satisfactorily meet this requirement. We also desire a seaplane for carrying bombs. This may be the same as the plane for carrying torpedoes. Both must be weight-carrying machines of a reasonable degree of speed. They must be capable of being operated from the decks of seaplane carriers, or from land near places where naval engagements may possibly take place.

The final type of seaplane that we are particularly interested in at present is one of large size, for long-distance reconnaissance work, somewhere between 500 and 1000 miles. As types of construction evolve and we develop ability to make the structure lighter, we will increase that range. At present, the N-C type is a fairly good machine of that sort, up to 500 miles. It is necessary to increase this range, and we are planning to design for greater size in order to meet that requirement.

Lighter-than-Air Craft

Two types of lighter-than-air craft are under development. One has already been very largely developed. It is a comparatively small non-rigid airship, for coast patrol and convoy work. In the "C" class of non-rigid airship, there already exists a very satisfactory machine for those purposes and for long-distance reconnaissance work up to 1500 miles. We are figuring on the rigid airship and we are buying a rigid airship from the British. We are also planning to build some ourselves. We have started on the preliminary work, and by the end of the year expect to have made good progress.

The carrying out of the program I have outlined depends upon several elements. The appropriations provided by Congress are one element. We feel that it will provide appropriations for development work only; we

hope that it will provide sufficient for that. If so, carrying out the traditional policy of the Navy Department with regard to air-service development, you automotive engineers will be counted upon to help us in the work of producing the types of aircraft that we need. We realize in the Navy department that the way to solve a problem is to get the greatest mass of brains impinging upon it. In no case is that more true than in the question of original development. We are counting upon the Society of Automotive Engineers and the aeronautical fraternity in general to assist in the problems of development that confront us.

We cannot pretend to this Society and to the aircraft manufacturers that we will be able to assist in production matters to any great extent. We do not expect to have the necessary money during the next two or three years to encourage production. This is regrettable because we realize that we must look to the commercial development for a large part of our own naval development. We cannot use commercial machines, but we can use the same materials, manufacturing facilities, mechanics, designing skill and skill of every sort that enter the development and manufacture of commercial machines.

Separate Air Service

Regarding the question of the separate air service, I will comment briefly upon the attitude of the naval service. Very few Navy men have been called into the discussion. I feel absolutely certain that the Navy feels that to take naval aeronautics away from the naval service would be a very great mistake. The Navy thinks not in terms of the battleship service, the destroyer, the submarine or the air service, but purely in terms of the naval service. It cannot be realized by anyone except persons who have lived for some time in the atmosphere of the naval service, that the Navy is made up of various elements, all necessary to its whole, and that if any one of those elements is removed the whole is incomplete. In the naval service, we believe that if naval aeronautics were taken away and placed under a separate organization, it could not develop with the spirit of the naval service, or along the lines which the naval service considers necessary. Therefore, we feel, and fear, that naval aeronautics will come to a standstill if taken out of the naval service and placed under a separate organization.

So far as the personnel of the naval air service is concerned, we believe that its place is in the Navy as a part of the Navy. We want to stay in the Navy, we look with disfavor, even with fear, upon being transferred to a separate organization. This is not a selfish viewpoint, because the probability is that all members of the naval air service would, if transferred to a separate organization, benefit very much in rank and in emoluments.

I wish to say that anyone who works for a separate air service, at the expense of the naval air service, is taking steps, so far as the Navy is concerned, which the people in the Navy believe will not be for the benefit either of the Navy or the country. They believe that those who are working with the object of maintaining in the Navy, and in the Army, the control of their own military aeronautical affairs, are working not only in the interests of the military arms, but of the country as a whole. We in the service look to you confidently to base your decisions only upon the cold logic of reasoning, and then cooperate with us if you can. We assure you that we will cooperate with you, and we look to you for assistance.

REMARKS BY AIR COMMODORE L. E. O. CHARLTON

WHEN I landed in this country about a year ago, to take up my present appointment, I found the Aeronautical Show of 1919 in full swing. It can only be gratifying to realize, as all must do, how successful has been the endeavor of those in the industry to turn the science of aeronautics from the side-track to which it was shunted during the war toward the main line of commerce, because the commercial machine will undoubtedly mean more for the defence of the country in an emergency, if properly developed, than other forms. Although the progress of the last year has been steady, it cannot be said to have been very great in volume. The volume of production in the coming year might be increased, apart from the unlimited loosening of purse strings, by a country-wide propaganda education of the public. Propaganda in this form no longer exists in my own country; it was supplied to us by our enemies. No less than 50 per cent of the inhabitants of the British Isles, either directly or indirectly, were witnesses of or sufferers from the visitations of hostile aircraft during the war. They were thus provided with a free education as to their deadly effectiveness and taught the absolute need of an adequate air fleet. Thus was provided the incentive to the great public, with the result that now the total aeronautical energy of the country is amalgamated into a separate Government department and most of the funds at its disposal are devoted to experiment and research. You were deprived of that, but the penalty you pay is perhaps an optimistic outlook in the country at large as to the needs of aeronautics.

I will touch only in a general sense on the controversial matter which I am aware exists in this country as regards the need of a separate air service. No one knows better than I the different problems that different countries have; and that different countries have different and efficacious methods of solving the same problem. I will therefore conclude with the allegory that a growing tree can stand by itself; that the sapling even, if of sturdy growth, can grow straight; but that the tendril, unless it is deformed, must be supported.

REMARKS BY COL. THURMAN H. BANE

WE have had in this country for a number of years an Army and a Navy working by themselves, trying to solve the problem of the defense of the country. We now have a youngster, an air service, that thinks perhaps it ought to be allowed to take a share in the solving of the defense problems of the country. It appears that it is high time that these two full-grown individuals and this youngster should be required to work as one unit for the defense of the country.

It might be desirable to have a single department of defense, a secretary of war, for example, or a secretary of national defense. Under this secretary of national defense an Army, a Navy and an Air Service might be combined, having a single general staff composed of officers of the Army, the Navy and the Air Service. The handling of all problems of defense would then be combined in one unit and coordination and liaison would exist, that certainly do not and cannot exist under the separate organizations we now have.

ADDRESS OF GEORGE H. HOUSTON

WHEN I was asked to talk here this evening, I was very directly reminded that this was to be an engi-

neering meeting, and that there were certain things I was not to talk about. I have listened with a great deal of interest to the talks we have just heard and I want to say to the representatives of the Army and the Navy here that the point of view they have expressed is one that should receive the most careful and painstaking attention on the part of the Congress in this country, in working out this aircraft problem. I would also say, however, that there are certain political, psychological, financial and administrative aspects of the problem, which in the analysis they have made this evening have not been taken into consideration. I do not propose to discuss them this evening. I believe that there are two sides to this vitally important question, and I am frank to say that the final answer has probably not yet been reached. I hope it will be reached in a short time, because I believe the difference of opinion and the resulting deadlock are doing more to stagnate the development of aeronautics in this country than all other influences together.

I have been closely associated with the development of the aeronautical industry since it was practically nothing but a production industry for our Allies. I have given the future development of it considerable thought. The aspect of future development that has struck me more forcefully than any other is that before aeronautics can become of great importance to this country, it must be more generally understood by the people of this country, as a whole; that is, they must grasp the problems that aeronautics will solve, and the problems that aeronautics brings. In other words, they must get the point of view of this new thing that has come into our lives, before real progress can be made.

The history of civilization, from its earliest inception, has been a story of the development of methods of communication and transportation. Man early learned to use animals as beasts of burden, and to transport himself by physical labor upon the surface of the water. He later learned to use the wind as a means of propulsion upon the water; but beyond this point little progress was made for many ages. With the invention of the steam engine, great strides were made in the development of the locomotive and the steamship. It is needless to call attention to the way in which these two developments have revolutionized man's entire point of view toward life. It is hard to believe that the first steamship crossed the Atlantic only one hundred years ago, that the first railroad crossed this continent scarcely fifty years ago, or that the first automobile was made in this country in 1893.

Great as has been the effect upon the life of man of the development of these modes of mechanical transportation, the ultimate effect of aerial flight will be still greater. Man dreamed of flying for hundreds of years. We read of how Leonardo da Vinci, among all of his enterprises in art and engineering, dreamed and worked for a solution of the great problem of human flight, but without success. This effort continued from generation to generation with apparently no progress toward the solution of the reason why man cannot fly as readily as the birds. Many of the greatest scientists of modern times have given much time and thought to the determination of this problem; but it remained for two unknown youths, with little technical education, to discover the principle upon which human flight depends.

Man successfully flew for the first time when the Wright brothers proved their invention by flying at Kitty Hawk, N. C., Dec. 17, 1903. It was not until 1908, however, that the world became convinced that human flight was possible. Many will remember how the papers scoffed at Wilbur Wright at LeMans, France, for his presumption in thinking he could fly, and how the sentiment reversed itself when his triumphant flights were witnessed. During the same year the Wright brothers flew before the rulers of England, France, Italy and Germany, and Orville Wright flew at Fort Myer near Washington. The result of these efforts was the recognition throughout the world of their contribution to the science of aerodynamics and to the art of flying. Others in America, France, England and Germany, were also studying this problem of human flight, but the progress was slow. Many of the best and most aggressive persons working for its solution were killed by accidents, and their work destroyed. During this period much speculation was indulged in as to the usefulness of the airplane and the dirigible for the practical requirements of man, but when in 1914 the world war began it was shortly discovered that aircraft are of great value in military operations. The science of aerodynamics and the practical production and use of aircraft were still in an embryonic condition. Probably no art or science in the world's history has developed so rapidly as the art of human flight since 1914. The history of this development when written will make the development of the railroad and the steamship appear very slow by comparison. In 1908 the Wright brothers sometimes flew as long as 30 min. at a time. In 1919, only eleven years later, and after five years of exclusive use of aeronautical equipment for purposes of warfare, we find the airplane and the dirigible coming into daily use in every part of the world for many kinds of military and commercial uses.

Looking over the entire field of aeronautical activity, we see before us the beginning of a vast industry whose growth throughout the world during the next decade will be phenomenal, and probably beyond the expectation of the most sanguine. This growth involves the solution of many serious problems, however, and I regret to say that they are not being given the consideration here in the United States that they deserve or that they are receiving abroad. It was the inventive genius of American citizens that first made human flight possible. Daring and resourceful American citizens first spanned the Atlantic by human flight, the initiative of an American Government official first made aerial mail transportation a practical success; but in general we are not giving to the solution of our aeronautical problems the farsighted constructive thought that it deserves and requires if we are to keep abreast of foreign progress. The problems involved in this development are complex and difficult and their practical solution can be achieved only by the thoughtful attention of everyone concerned. I group these problems into four general classes

(1) International relations
(2) National control
(3) Commercial, industrial and technical development
(4) Provision for national defense

International Relations and National Control

Due to the high speed of transportation and the great distances covered, human flight is of necessity an international activity. This is, of course, truer of European countries than it is of America; but even in America we are already confronted with the problem of planes flying across the border to and from Canada, Mexico, Cuba and the Bahamas.

Aeronautical transportation between the Bahama Isl-

ands, Cuba and Florida, promises to grow with unprecedented rapidity due to recent developments within the United States itself; so that even this country must recognize the international character of aviation and make provision accordingly. This aspect of the situation has long been given careful study by European countries and, as a part of the peace negotiations, a conference was held in Paris, attended by representatives of all the Allies, for the preparation of an international agreement setting forth the principles which shall govern the control of air flight between the nations of the world. This agreement was accepted by the representatives of the United States subject to the ratification of the Senate, with certain reservation which in the opinion of the American industry were justifiable and reasonable. This international convention was remarkable and a very effective start toward international aviation law; it has been ratified by every one of the Allies except the United States, Japan and Canada. Its early ratification by the United States would probably be followed shortly by its ratification by Canada, and would mean the establishment of effective international regulation of air flight on this side of the Atlantic.

This international agreement, however, involves certain undertakings on the part of the United States which deserve immediate and careful attention, whether the convention is ultimately ratified or not. These obligations pertain to the control of the construction and use of aircraft in general

(1) To prevent improper and dangerous craft being built
(2) To prevent craft being improperly operated, either through ignorance or carelessness
(3) To define the rules of aeronautical commerce in conformity with international practice; so that uniform methods of operation, signaling, landing, etc., will develop throughout the world

The development of the steamship with its great power and high speed brought about a necessary central control of the construction and operation of steam craft of every kind. This activity has long been recognized as a very proper and legitimate function of the Federal Government. Control of the construction and operation of aircraft is in my opinion an equally legitimate and necessary undertaking of the Federal Government.

The necessity for a body of law to adequately govern in the new conditions that will exist when air flight becomes commonplace has been recognized by the American Bar Association by the appointment of a committee made up of a member from each State, charged with the task of formulating a code of law for the government of aeronautical transportation. William Rocker, chairman of this committee, has presented the problems involved in a very broad-minded way. He calls attention in particular to the similarity of conditions existing in the navigation of ships of the air and ships upon the water, and to the fact that we have a great mass of precedents and customs in our maritime laws that will be of considerable value to us in developing this new field; but that in applying the principles of maritime law to aeronautical transportation we must be exceedingly careful to recognize the essential differences and not encumber the field of aeronautics with undesirable and obstructive legal procedures.

Industrial and Technical Development

Aeronautical transportation as a commercial activity cannot become a fact until conditions surrounding the use of aircraft are established in such a way as to create stability and safety of operation, regular routes of commerce and reasonable economy. Given reasonably intelligent construction of aircraft and correspondingly intelligent operation, there is little risk in aerial transportation, except as to the dangers involved in landing. These dangers can be almost entirely overcome by properly constructed and well-located landing fields.

Landing fields to be of use must be properly equipped with modern signaling and communicating systems, so that aircraft flying above the clouds, out of sight of the earth, or in foggy weather, can keep in constant wireless communication with their landing places as they fly. The mechanical devices necessary for such signaling and communication are already well perfected and a recognized part of the equipment of every modern flying field.

Meteorological information, which is extremely difficult and expensive to gather by private means, must be at hand to let the mariner of the sky know the kind of weather he will encounter and to warn him to drop down into harbor or go up into clear weather in the event of dangerous squalls appearing. This kind of service is even more essential to aircraft than it is to watercraft upon the ocean or our lakes.

Regular routes along the natural lines of commerce are essential so that business requiring the service of aerial transportation will know exactly where to find it. Just as the railroad must have a well-established terminal and carefully indicated way stations with properly prepared and maintained timetables, so must commercial aviation have established routes with properly indicated terminals and way stations adequately equipped for the maintenance of aircraft and the caring for goods and passengers, so as to permit of regular and systematic operation.

Coupled with this development of the external conditions which are necessary to facilitate the use of aircraft, the proper development of the craft itself must be continued. We all realize that remarkable progress is being made in this direction and yet there is still much to be desired. The latest news from Germany is to the effect that one line of dirigibles has carried passengers over 250,000 miles without a single injury. Yet I was told by a man recently returned from Germany that one of these dirigibles recently up-ended in a severe wind, and precipitated everyone very unceremoniously into one end of the cabin; as a result, the flight had to be postponed until the next day and then only five of the original passengers had the nerve to return. Again we are told in the official reports that civilian aviation in England in eight months flew over 590,000 miles with only five fatalities, one passenger and four aviators. On the other hand, we all know that a leading American banker recently lost his life in an accident in the London-Paris aviation service. These conditions all indicate that our mechanical equipment is still far from being as perfect as it should be.

The development and perfection of this equipment are the particular problems the members of this Society are being asked to cope with. I refer to this not in criticism of what has been accomplished in the past, which has been truly remarkable, but to emphasize the vital importance to the success of commercial aeronautical transportation, of continued development in this direction. This field is so great, involving as it does motive power, heavier-than-air and lighter-than-air craft, accessories and instruments of all kinds, that we must realize the wonderful possibilities that remain.

Progress is possible only through extensive laboratory

and experimental work of an unusually expensive nature, as for instance the altitude flights that have recently been made by Major Schroeder and others in an effort to come to a clear understanding of the conditions of the upper atmosphere. It is not practical to expect the private enterprises now behind this infant industry to support all of this experimentation, particularly as the greater part of it is of immeasurable value to the Government for purposes of national defense and otherwise. While it is exceedingly undesirable for the Government to undertake to design its own craft, instead of developing such detailed design by private initiative through competition, yet it is desirable for the Government to carry on this fundamental experimental work. To this end there must be maintained an organization properly equipped for the testing out of any new equipment that is brought to it, and for the carrying on of such experimental work as is necessary to properly establish the science of aerodynamics.

There are no insurmountable difficulties in working out any of these problems, or in establishing these aspects of commercial aviation. The one great remaining difficulty, however, is almost insurmountable at present. I refer to the matter of reasonable economy of operation. It is at this point that the aeronautical industry requires the assistance of Federal, State and municipal Governments. Just as the nation and the communities have built a net-work of roads throughout the country for the transportation of vehicles, just as Federal and State Governments, and municipalities gave all possible encouragement in the early days through grants of land and otherwise to the construction of railroads, and just as the Federal Government and municipalities undertake today to develop our harbors and water-ways, so it is necessary the aeronautical transportation industry be helped to establish the conditions under which air flight must be carried on. I do not mean by this that the industry of aircraft production should be subsidized. The development of the production industry is in reality not the solution of this problem, in that it bears about the same relation to aeronautical transportation that the production of locomotives and freight cars bears to the railroad transportation problem. Given a profitable and well-organized aeronautical transportation industry, the production of aircraft and aircraft equipment will take care of itself upon a satisfactory and self-supporting basis; but in my opinion aeronautical transportation in the United States will develop with exceeding slowness and will be far outstripped by similar development in foreign countries unless the Government of the United States and the Governments of the States and municipalities, each actively participate in the development of flying routes, in the preparation and equipment of flying fields, in the provision of adequate signaling and communication systems, meteorological service and the carrying out of extensive technical experimentation. I am confident on the other hand that with well-established flying routes equipped with adequate flying fields properly located and provided with the resources above enumerated, commercial aviation will become a fact throughout all of this country to an extent undreamed of at the present time.

Providing for National Defense

This brings me to the fourth aspect of our aeronautical problems as I see them today, provision for national defense. That aircraft of all kinds are already an important factor in provision for national defense and in the very near future will become a dominating factor, is, I believe, a foregone conclusion. If this is true, then it behooves our Government to make provision for an adequate supply of aircraft personnel and equipment in its plans for national defense of the future. The experience of the United States during the war, in its effort to produce great quantities of aircraft without adequate knowledge or preparation, will be repeated unless the lessons learned in the past are taken to heart for the future.

Aeronautical equipment is essentially complicated and difficult to produce. Skilled fliers cannot be made over night, and undue rushing of their training is liable to lead to disastrous results. Such training can only be had by the use of extensive flying facilities of both fields and craft. As a result the development and maintenance of a large air force for military purposes will be found to be expensive and onerous to the tax payer, particularly as the design of craft and methods of operation are developing and changing so rapidly that what is effective equipment today is obsolete before tomorrow comes.

The only practical way in which the Nation can be prepared with an adequate supply of aircraft for its protection in case of necessity is to develop a large aerial merchant marine, made up of an extensive personnel trained to constant flying, and a mass of flying and production equipment the greater part of which would be applicable to military purposes in case of need. I will grant at once that aircraft used for commercial purposes is not altogether effective, or even desirable, for military purposes. It would be effective, however, for internal transportation and training purposes, and the production facilities and organization used for making commercial craft and the technical facilities used in the designing and development of commercial craft would be immediately available for the production of military craft in the shortest possible time. It was the lack of this technical experience and of the production facilities and personnel that made the production of aircraft in the United States during the late war such an insurmountable problem. It would of course be necessary to have a nucleus of military craft and personnel trained to the highest possible degree in the science of aerial warfare. Such a military air service in time of war would maintain the same relation to the air service as a whole as the regular Army maintained to the Army of the United States during the late war.

I have endeavored to indicate very briefly the problems confronting those who are endeavoring to develop the art of human flight to a place of practical utility in the commerce of the United States. You will recognize at once that the Federal Government must, through its interests in national defense, mail transportation, coast patrol, forest patrol and the maintenance of its international relations, take a very active part in this development. If this cooperation and supervision is given I am confident that America will again lead the world in aeronautical development. Considering the vast distances of this continent and the great stretches of coastline, all of which are ideal for aerial transportation, this is as it should be. I look forward with confidence to the time when the flight of human beings from point to point throughout this country will be carried on as conveniently and will be taken as much a matter of course as their movement by railroad or automobile.

Current Flight Mileage and the Future

Scarcely sixteen years ago the Wright brothers made four flights, the longest being 852 ft. During the eight

months from May to December, 1919, in England alone in civil aviation, exclusive of the competition flights from England to Australia, over 590,000 miles were flown. When American, French, Italian, German, Japanese and other civilian aviation is included, and military aviation is considered, it will be seen that the human race flew in the past year probably in excess of 2,000,000 miles.

Today man has surpassed the flight of birds in every particular except one, the safety with which he alights. He has flown higher and farther and more rapidly than any bird that has ever lived or ever will live. It is only a matter of time when he will learn how to alight with security equal to that of his other attainments. If such progress has been made in the past sixteen years, let us consider what we may expect in the next ten and lay our plans accordingly.

The Society of Automotive Engineers has an opportunity during the next few years to be of great value in the development of this new industry, through the perfection of the mechanical equipment which it requires and through the exercise of its influence in bringing about the conditions necessary for the successful carrying on of commercial aeronautics.

REMARKS OF MAJOR MAURICE CONNOLLY

THE great secret of the whole development of aeronautics is the establishment of landing fields. As far as Government support and Congressional appropriations go, present conditions are not on as large a scale as we could hope, but in the solution of the problems involved we must have courage, faith, vision and ideals. We must realize our ideals through the research, invention and work of men such as you.

I believe that if we all pull together with zeal in determination to give to this country an aviation program commensurate with the importance of this Nation among the nations of the world, we will share in the reward that comes to people who maintain the faith and who keep their courage. We may not be able to get the remuneration that obtains in other lines, but we will have the satisfaction when the work is done that we have contributed our portion; that we have given all that is in us to promote the heart of progress, and made by intercommunication by means of the new transportation a substantial contribution to civilization.

PROGRESS OF THE AIR SERVICE

SOME of the developments in the fighting air service since the signing of the armistice include

(1) Three new types of pursuit airplanes, with speeds approximating 150 m.p.h.
(2) Three different types of cannon for use of aircraft
(3) An anti-leak gasoline tank that has successfully withstood rigid tests with service ammunition

In the experiments we have fired forty-seven rounds of service ammunition into these tanks, alternately using ordinary service bullets, armor-piercing bullets and incendiary bullets. All failed to produce a leak or any explosion in the tank.

These experiments emphasized the need of further increasing the caliber of the weapon we would have to use against an enemy, so the Ordnance Department has been concentrating upon the production of various caliber cannon for use on pursuit ships and other aircraft.

We have a 37-mm. cannon that has given remarkable results, and experiments are now being made with a 3-in. cannon on aircraft. All show signs of success. Some of the ships on the Mexican border are being equipped with these weapons.

The ordnance pursuit biplane, which has been developed by the United States Air Service, has given far better results than the French Spad and has a lower landing speed than the French machine.

Another pursuit biplane is the new Thomas Morse type that is undergoing development. Both these ships are far superior to the smaller types in Europe in maneuverability and speed.

On the Mexican border the Air Service now has 300 rebuilt De Haviland Fours, in which the pilot has been placed back of the gasoline tank.

This has greatly increased the safety of this type of machine for the pilot, and brought the pilot and observer close together. It has also given the pilot a greater range of visibility. Eight of these rebuilt machines crashed in the transcontinental air race without any injury to the personnel.

A third pursuit biplane has been designed by the technical staff of the Air Service, and is still an experimental machine. It is completely stream-lined and has a monocoque, or circular body built of veneer. It is remarkably strong. This type has a peculiar radiator, and the wings are braced with very thick single struts.—From an address by Brigadier-General William Mitchell before the Flying Club (New York City).

LONDON-PARIS AIR SERVICE

FIGURES are available on the London-Paris air service carried on for six months by two composite squadrons, one at Hendon, afterward moved to Kenley, and the other at Buc, near Paris. The machines used were chiefly DH-4's, but Handley-Page, Martinsyde and Bristol fighter types also were employed; all the machines being fitted with Rolls-Royce engines. This service was primarily for passenger work, although official mails and dispatches were frequently carried.

The total number of trips was 744; 934 passengers and 1028 mail bags being carried. A certain number of the flights were to various other French or Belgian towns; 90 per cent, however, were to Paris. Of the flights 556 were completed and 52 failed; 13 on account of weather conditions and the remainder owing to mechanical defect or engine trouble. The percentage of successful trips therefore amounted to 91.

The machines were not working to their full capacity. Naturally, the resulting cost was higher than would otherwise have been the case, but the data so obtained are interesting and valuable as indicating roughly the possibility of commercial aviation as a paying proposition. Allowance was made for depreciation on buildings and plant of 5 per cent per annum on original cost, as well as rates and upkeep. Depreciation on the machines employed was charged for one month's running at one-twelfth of their initial cost, thus allowing a complete write-off of each machine in one year. Monthly depreciation of the engines was taken at one thirty-sixth of the initial cost. This is of course in addition to the full charges for all personnel employed and all stores consumed. Taking the average weight of a mail bag as 25 lb. and of a passenger as 180 lb. and working on the figures of one month as representative, the actual cost worked out to 1s. ½d. per oz. per 205 miles, the actual distance between Kenley and Paris.

In the six months there were five accidents in which three pilots and one passenger were killed and two pilots and one passenger were injured.—Air Service News Letter.

AIR MAIL OPERATION AND MAINTENANCE

ACCORDING to figures compiled by the Post Office Department the cost of the Air Mail Service in the month of February averaged $1.17 per mile flown on the New York-Chicago route and $1.58 on the route between New York and Washington. These figures include overhead as well as costs of flying and maintenance. The total cost of service on the former route for the month was $31,774.43 and $14,229.69 for the latter. Details of these costs are given in the tables.

NEW YORK-CHICAGO ROUTE.

Airplane No.[1]	Gasoline	Grease and Oil	Pilots	Mechanics and Helpers	Repairs and Accessories	Interest on Investment	Departmental Overhead Charge[3]	Total[4]	Service and Unit Cost: Gasoline, gal.	Total Time Run, hr.-min.	Total Miles Run	Miles Run per Gallon of Gasoline	Cost per Hour	Cost per Mile
39-a	$4.20	$2.45	.....	$21.30	.....	$75.00	$112.36	$446.44	15	... ..	....	.....	....	...
40	.....	....	.....	71.20	$36.05	72.50	112.36	523.24	....	... ..	....	.....	....	...
46	96.60	....	$61.92	213.36	50.85	72.50	112.36	838.72	345	5 22	452	1.3	$156.30	$1.86
49	63.00	4.03	90.96	59.29	.....	20.15	112.36	580.92	225	7 53	610	2.7	73.68	0.95
60	.....	....	.....	5.50	143.72	50.00	112.36	542.71	....	... ..	....	.....	....	...
65	88.20	6.13	104.23	223.73	43.35	50.00	112.36	859.13	315	9 02	915	2.9	95.10	0.94
66	341.79	39.28	516.33	368.58	555.49	50.00	112.36	2,214.96	1,230	44 45	4,393	3.6	49.50	0.50
67	304.97	39.83	424.21	312.36	524.70	50.00	112.36	1,999.56	1,084	36 46	3,089	2.8	54.36	0.65
72	.....	....	.....	159.75	49.85	50.00	112.36	603.09	....	... ..	....	.....	....	...
75	351.03	46.14	494.21	385.59	438.06	50.00	112.36	2,108.52	1,265	42 50	4,158	3.3	49.20	0.51
76	.....	....	.....	97.17	3.48	50.00	112.36	494.14	....	... ..	....	.....	....	...
79	.....	....	.....	15.25	.....	50.00	112.36	408.74	....	... ..	....	.....	....	...
88	374.18	63.42	521.33	355.27	153.80	50.00	112.36	1,861.49	1,358	45 11	4,314	3.2	41.22	0.43
89	69.34	4.42	39.42	264.96	1,281.82	50.00	112.36	2,053.46	238	3 25	290	1.2	601.02	7.08
92	.....	....	.....	14.88	.....	50.00	112.37	408.39	....	... ..	....	.....	....	...
94	.....	....	.....	79.54	.....	50.00	112.37	473.05	....	... ..	....	.....	....	...
101	270.96	34.27	462.10	314.25	163.00	50.00	112.37	1,638.09	940	40 03	3,633	3.9	40.92	0.45
102	230.40	20.87	335.76	374.14	140.25	50.00	112.37	1,494.93	824	29 06	2,966	3.6	51.36	0.50
104	111.54	14.74	217.11	121.51	11.00	50.00	112.37	869.41	399	18 49	1,707	4.3	46.20	0.51
105	34.56	3.51	43.27	265.30	105.75	50.00	112.37	845.90	128	3 45	358	2.8	225.60	2.36
107	169.01	22.90	236.34	175.29	105.97	50.00	112.37	1,103.02	599	20 29	2,019	3.4	53.82	0.55
108	.....	....	.....	18.76	.....	50.00	112.37	412.27	....	... ..	....	.....	.....	...
111	66.36	16.25	.....	201.05	65.40	100.00	112.37	792.58	237	... ..	....	.....	.....	...
201	35.00	....	.....	186.65	110.05	200.00	112.37	875.22	125	... ..	....	.....	.....	...
202	7.00	4.00	.....	203.80	236.30	200.00	112.37	994.62	25	... ..	....	.....	.....	...
203	.....	....	.....	175.50	106.10	200.00	112.37	825.13	....	... ..	....	.....	.....	...
204	[2]	....	10.58	405.77	2,007.25	200.00	112.37	2,967.15	[2]	... 55	80	.....	.....	37.09
205	.....	....	.....	55.27	.....	200.00	112.37	598.80	....	... ..	....	.....	.....	...
206	[2]	....	24.10	366.46	132.17	200.00	112.37	1,066.26	[2]	2 05	145	.....	511.80	7.35
24227	.....	....	.....	54.90	19.25	50.00	112.37	467.68	....	... ..	....	.....	.....	...
44305	.....	....	.....	10.00	18.30	35.00	112.37	406.83	....	... ..	....	.....	.....	...
Totals	$2,618.14	$322.24	$3,581.87	$5,576.38	$6,501.96	$2,525.15	$3,483.33	$31,774.43	9,352	310 26	29,129	3.1	$102.36	$1.09

[1]No. 39-a, Curtiss HA, equipped with Liberty twelve engine, Nos. 40 to 49, inclusive, Curtiss R4, equipped with Liberty twelve engines, Nos. 60 to 108, inclusive, and 24,227 De Havilands, equipped with Liberty twelve engines, No. 111, Twin De Haviland, equipped with two Liberty six engines, Nos. 201 to 206, inclusive, Martins, equipped with two Liberty twelve engines, and No. 44305, Curtiss JN4D, equipped with Curtiss OX5 engine.

[2]Ran on gas put in during previous month.

[3]Includes $545.63 covering work preliminary to the inauguration of service between Chicago and Omaha.

[4]Includes $2,424.69 for office force and watchmen, $1,066.49 for motorcycles and trucks, $787.71 for rent, light, fuel, power, telephone and water, and $2,886.47 for miscellaneous expenses.

NEW YORK-WASHINGTON ROUTE.

Airplane No.[5]	Gasoline	Grease and Oil	Pilots	Mechanics and Helpers	Repairs and Accessories	Interest on Investment	Departmental Overhead Charge[6]	Total[7]	Service and Unit Cost: Gasoline, gal.	Total Time Run, hr.-min.	Total Miles Run	Miles Run per Gallon of Gasoline	Cost per Hour	Cost per Mile
12	$42.56	$14.00	$26.42	$83.01	$5.65	$46.24	$96.75	$607.43	152	2 15	195	1.3	$269.94	$3.12
30	24.92	11.76	34.25	123.60	1.80	72.50	96.76	658.40	89	2 55	170	1.9	225.72	3.87
31	208.40	49.95	263.02	207.29	68.58	72.50	96.76	1,259.31	815	22 24	1,935	2.4	56.22	0.65
33	.....	....	.....	149.51	2,801.63	72.50	96.76	3,413.21	....	... ..	....	.....	....	...
34	167.82	30.47	171.43	173.59	293.70	72.50	96.76	1,299.08	589	14 36	898	1.5	88.98	1.45
35	.....	....	.....	89.88	.....	72.50	96.76	551.95	....	... ..	....	.....	.....	...
43	190.80	45.11	243.05	191.30	31.40	72.50	96.76	1,163.74	745	20 42	1,286	1.7	56.22	0.90
48	178.92	55.99	164.78	307.22	98.20	72.50	96.76	1,267.19	665	14 02	982	1.5	90.30	1.29
49	193.34	38.37	196.29	255.35	76.03	52.35	96.76	1,201.32	678	16 43	1,586	2.3	71.88	0.76
50	180.84	20.07	156.99	214.48	568.45	72.50	96.76	1,602.92	633	13 21	1,082	1.7	120.06	1.48
110	87.08	24.12	95.89	78.11	1.80	50.00	96.76	726.59	311	8 10	840	2.7	88.98	0.86
44301	8.08	2.94	8.81	30.97	3.15	35.00	96.76	478.55	36	... 45	55	1.5	.....	8.70
Totals	$1,282.76	$292.78	$1,360.93	$1,904.31	$3,950.39	$763.59	$1,161.11	$14,229.69	4,713	115 53	9,029	1.9	$122.82	$1.58

[5]No. 12, Curtiss JN4H, equipped with Hispano Suiza eight engine, Nos. 30 to 50, inclusive, Curtiss R4, equipped with Liberty twelve engines, No. 110, De Haviland equipped with Liberty twelve engine, and No. 44301, Curtiss JN4D, equipped with Curtiss OX5 engine.

[6]Includes $181.87 covering work preliminary to the inauguration of service between Chicago and Omaha.

[7]Includes $1,376.63 for office force and watchmen, $960.16 for motorcycles and trucks, $422.05 for rent, light, fuel, power, telephone and water, and $754.93 for miscellaneous expenses.

Plywood and Its Uses in Automobile Construction

By Armin Elmendorf[1] (*Non-Member*)

Cleveland Section Paper *Illustrated with* Charts and Photographs

FOR many years plywood has been used for such automobile parts as roofs and dash and instrument boards, but it was not until the closing of the European war that the extent to which this material was used in automobile construction greatly increased. The explanation of this comparatively sudden demand lies in the improvements in the method of manufacture resulting from the requirements for war material. Prior to the European war practically the entire output of plywood used in automobile construction was glued with common non-water-resistant hide or vegetable glues. On account of the ever-present danger of the separation of the plies glued with these glues when exposed to rain, its extensive use in automobile construction was never realized.

The sudden requirement of airplanes during the war created a large demand for plywood which would withstand the severest weather conditions. Glues were perfected that enabled the Government to draw up specifications requiring that the plywood withstand 8 hr. of boiling or 10 days of soaking in water without separation of the plies. With the perfection of its water-resistant qualities the remaining highly desirable properties of plywood as a structural material for airplanes were made available. In the construction of aircraft strength per unit of weight was the most important factor. In this respect plywood compared favorably with all other structural materials, including high-grade steels. Large quantities were required, particularly thin flat sheets of large area for fuselage construction. Fuselage material must also show a minimum distortion or warping with changes in atmospheric conditions. It must possess high resistance to splitting, must not splinter, must be stiff, absorb rather than impart vibration, and it is necessary that it be moldable. Each of these requirements was fulfilled to a satisfactory degree by plywood.

It so happens that the properties of a material for many parts of an automobile must fulfill exactly the same requirements demanded for airplanes. In order that the power consumption of the car may be kept at a minimum, the weight must be reduced. Materials used should therefore yield maximum strength per unit of weight. They must lend themselves to a good finish and be workable with conventional mechanics' tools. Plywood also fulfills each of these requirements.

Plywood as an Engineering Material

Much of the antagonism that existed in former years to plywood as a structural material can be attributed to the name commonly applied. The term "veneer" was quite generally used irrespective of the number of plies or of the details in the construction. This word carried with it an impression of concealment as if thin sheets of wood of a fine quality were glued over a base of poor material, with the result that the defects in the latter were hidden. Frequent peeling of the face plies also contributed to a general disfavor of this material. In the terminology now being adopted by the industry, the word veneer refers to the individual sheets of thin wood, while plywood is used for the assembled glued-up stock. For automobile parts grain or appearance is usually a secondary consideration, the mechanical properties being of much greater importance. It for this reason that plywood is now frequently spoken of as an engineering material. Like steel or concrete it has certain definite strength properties which, if they are known, can be used in engineering design. With the exception of its use in instrument boards, plywood is an engineering material in automobile construction. Similar to the plywood which was used in building airplanes, that which is now demanded by the automobile industry may be soaked or boiled in water for many hours without separation of the plies.

With the disappearance of the objections to plywood resulting from the perfection of this material during the war and the knowledge that it can be molded to conform to fuselage sides, the demand for plywood roofs rose. Several large automobile companies now favor this material to the exclusion of all others for the roofs of their closed cars. It is also being extensively used for cab roofs. Three-ply wood of a total thickness of about 5/16 in. is in common use. Panels for roofs have a core or center ply that is usually between two and three times the thickness of the face plies.

In addition to its use for roofs plywood is extensively used for the following automobile parts:

Dash-boards
Instrument boards
Door linings
Window frames

Plywood is not applied as yet very extensively to the construction of automobile bodies and disk wheels. The difficulty that must be overcome before plywood can be very widely used for automobile bodies lies in the fact that it cannot be bent in severe double curvature. It cannot be molded to the form of most standard bodies.

The weight of the conventional plywood disk wheel has militated against its extensive use for wheels, but by proper design the weight can be materially reduced so that the advantage of great strength per unit of weight can also soon be realized in wheels.

Plywood Compared with Ordinary Boards

Wood, as is well known, is a non-homogeneous material, that is, its strength properties are different in different directions. Parallel to the grain the tensile or pulling strength of a board may be as high as 20,000 lb. per sq. in., while at right angle or across the grain the tensile strength may be only 1000 lb., that is, in the former direction the tensile strength may be twenty times as

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high as in the latter direction. Practically the same ratio exists for the stiffness or modulus of elasticity in these two directions, that parallel to the grain may be 2,000,000 lb. per sq. in., while at right angles to the grain it may be only 100,000 lb.

In all standard plywood constructions the grain of one-ply crosses that of the adjacent plies at right angle. With this distribution of the wood fibers a very marked increase in the strength across the face grain of a board is obtained. By a proper selection of the thickness of the center ply the strength across the grain of the face are given in Table 1. The strength values listed in this table are for three-ply wood in which all plies of a given panel are of the same thickness and of the same species, the grain of the successive plies running at right angles. In most cases eight thicknesses of plywood ranging from 1/10 to 3/16 in. were tested. In some of the species listed the tests were limited in number. Since a marked variation in the strength of the wood is shown, further tests on additional material would be expected, according to the laboratory officials, to modify the values appreciably in some cases. The weight of plywood made of

TABLE I.—STRENGTH OF VARIOUS SPECIES OF THREE-PLY PANELS.

Species	Average Specific Gravity of Plywood Based on Oven-Dry Weight and Volume at Test	Average Moisture, per cent	Column Bending						Tensile Strength				Splitting Resistance	
			Column-bending Modulus				Modulus of Elasticity, 1000 lb. per sq. in.		Parallel		Perpendicular			
			Parallel[2]		Perpendicular[2]									
			No. of tests	Lb. per sq. in.	No. of tests	Lb. per sq. in.	Parallel	Perpendicular	No. of tests	Lb. per sq. in.	No. of tests	Lb. per sq. in.	No. of tests	Per cent of Birch[3]
Ash, black	0.49	9.1	120	7,760	120	1,770	1,070	96	120	6,180	120	3,940	240	73
Ash, commercial white	0.60	10.2	200	9,930	200	2,620	1,420	143	200	6,510	200	4,350	400	71
Basswood	0.42	9.2	200	7,120	200	1,670	1,210	85	200	6,880	200	4,300	400	63
Beech	0.67	8.6	120	15,390	120	2,950	2,150	167	120	13,000	120	7,290	240	94
Birch, yellow	0.67	8.5	195	16,000	200	3,200	2,260	197	200	13,210	200	7,700	400	100
Cedar, Spanish	0.41	13.3	115	6,460	115	1,480	1,030	84	115	5,200	115	3,340	230	60
Cherry[4]	0.56	9.1	115	12,260	115	2,620	1,630	152	115	8,460	115	5,920	230	80
Chestnut	0.43	11.7	40	5,160	40	1,110	740	75	40	4,430	40	2,600	80	74
Cottonwood[5]	0.46	8.8	120	8,460	120	1,870	1,440	109	120	7,280	120	4,240	240	85
Cypress, bald	0.45	8.0	113	8,890	113	1,850	1,220	95	113	6,160	113	3,980	148	49
Douglas fir[6]	0.48	8.6	176	9,340	200	1,940	1,530	126	200	6,188	200	3,910	374	63
Elm, cork	0.62	9.4	65	12,710	65	2,500	1,980	136	65	8,440	65	5,500	130	99
Elm, white	0.52	8.9	160	8,680	160	1,970	1,220	109	160	5,860	160	3,990	320	75
Fir, true[7]	0.40	8.5	24	9,200	24	1,811	1,580	100	24	5,670	24	3,770	48	60
Gum[8]	0.54	10.6	40	8,090	40	1,920	1,280	113	35	6,960	35	4,320	70	55
Gum, cotton	0.50	10.3	80	7,760	80	1,580	1,300	111	80	6,260	80	3,760	160	60
Gum, red	0.54	8.7	182	9,970	182	2,070	1,590	120	182	7,850	182	4,930	364	80
Hackberry	0.54	10.2	80	8,100	80	1,880	1,150	99	80	6,920	80	4,020	160	84
Hemlock, Western	0.47	9.7	119	9,250	119	1,960	1,580	112	119	6,800	119	4,580	238	63
Magnolia[9]	0.58	8.8	80	10,830	80	2,600	1,700	138	80	9,220	80	5,730	120	85
Mahogany, African[10]	0.52	12.7	20	8,070	20	2,000	1,260	144	20	5,370	20	3,770		
Mahogany, Philippine[11]	0.53	10.7	25	10,160	25	2,310	1,820	169	25	10,670	25	5,990	50	90
Mahogany, true	0.48	11.4	35	8,500	35	1,940	1,250	117	35	6,390	35	3,780		
Maple, soft[12]	0.57	8.9	120	11,540	120	2,420	1,750	145	120	8,180	120	5,380	240	106
Maple, hard[13]	0.68	8.0	202	15,600	202	3,340	2,110	189	192	10,190	202	6,530	404	114
Oak, commercial red	0.59	9.3	115	8,500	115	2,070	1,290	120	115	5,480	115	3,610	230	70
Oak, commercial white	0.64	9.5	195	10,490	195	2,310	1,340	118	195	6,730	195	4,200	390	85
Pine, sugar	0.42	9.4	65	8,050	70	1,670	1,310	90	70	5,430	70	3,690	140	47
Pine, white	0.42	5.4	40	10,130	40	2,050	1,570	111	40	5,720	40	3,340	80	31
Poplar, yellow	0.50	9.4	165	8,860	165	1,920	1,540	115	155	7,390	165	4,720	330	51
Redwood	0.42	9.7	105	8,230	105	1,550	1,180	108	105	4,770	105	2,960	210	48
Spruce, Sitka	0.42	8.3	121	7,710	121	1,690	1,370	105	121	5,650	121	3,410	224	78
Sycamore	0.56	9.2	163	11,040	167	2,340	1,630	130	163	8,030	163	5,220	326	77
Walnut, black	0.59	9.1	110	12,660	110	2,770	1,740	141	110	8,250	110	5,260	220	77
Yucca species	0.49	7.3	33	2,960	33	900	560	44	33	2,210	33	1,700	66	14

[2]Parallel and perpendicular refer to the direction of the grain of the faces relative to the direction of the application of the force.
[3]The relative splitting resistance of the various panels tested depends largely on the holding strength of glue.
[4]Probably black cherry.
[5]Probably common cottonwood.
[6]Coast type.
[7]Probably white fir.
[8]Probably black gum.
[9]Probably (Evergreen) magnolia.
[10]Probably Khaya species.
[11]Probably tanguile.
[12]Probably silver maple.
[13]Sugar or black maple.

of three-ply wood is readily made equal to that parallel to the face grain. To obtain equal tensile strengths the thickness of the core of three-ply wood is made equal to one-half the total thickness of the panel. For equal bending strength the core thickness should be about two-thirds of the total thickness.

The results of extensive tests made by the United States Forest Service at the Forest Products Laboratory, Madison, Wis., on the mechanical properties of plywood any of the species listed can be computed from the specific gravities tabulated in the first column. It will be seen that the well-known relation between strength and weight for ordinary wood also holds for plywood, that is, the strength in bending or in tension increases rapidly with increase in the weight. The column bending modulus is a measure of the strength in bending and can be used in computations similar to those involving the modulus of rupture of ordinary wood. It must also

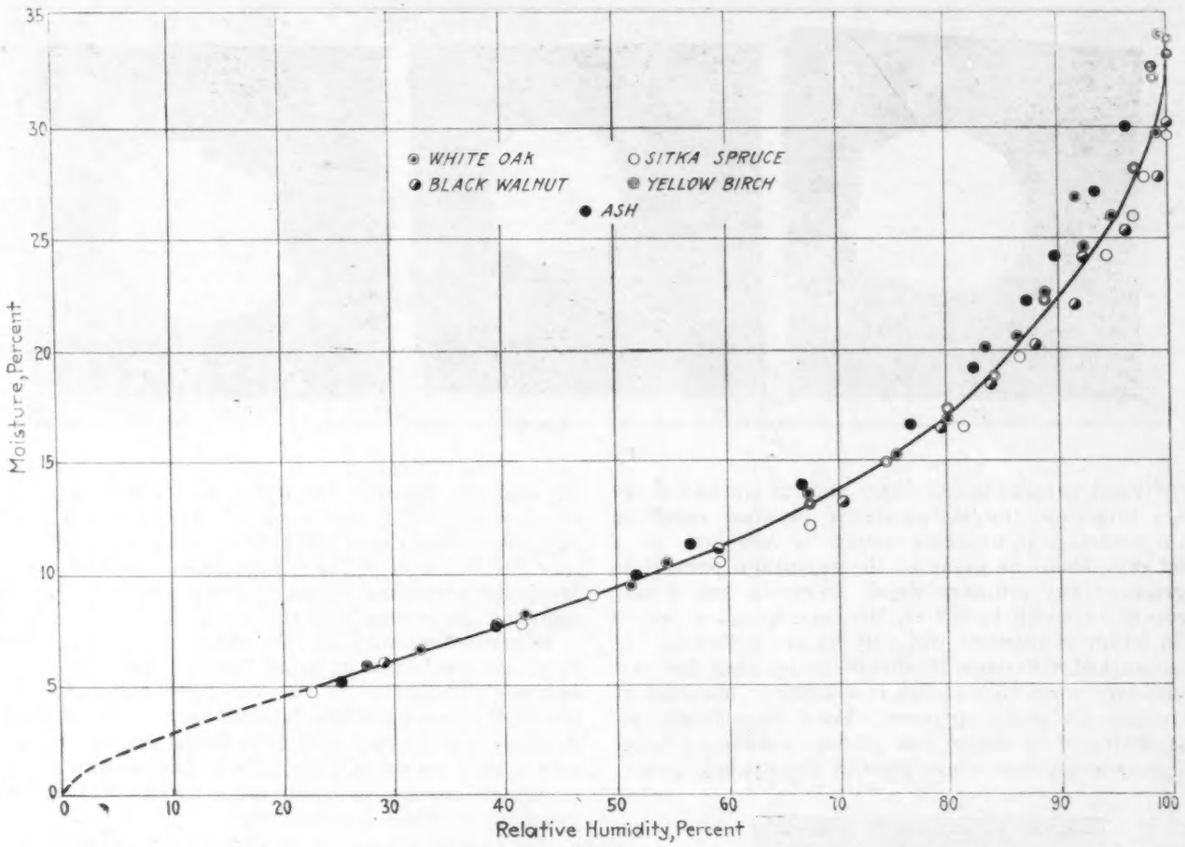


Fig. 1

be remembered that the strength is greatly affected by the moisture content, increasing with reduction in moisture content.

On account of the great influence of the moisture content of wood on its properties, the factors which influence the moisture content should be understood. It is, for example, not always necessary to submerge wood in water to increase its moisture, nor will mere exposure to high temperatures necessarily reduce the moisture content. By exposing wood to relatively high atmospheric humidity its moisture content can be increased, while exposure to low humidities such as in an arid country may greatly lower the moisture content. It is a common observation that the moisture content of the wood in a room kept at 70 deg. fahr. in winter is much lower than that of the same piece of wood in summer when it is exposed to the free circulation of air at the same temperature. The relation between the relative atmospheric humidity and the percentage of moisture contained by wood is quite definite and is practically the same for many species. This relation is shown in the curve of Fig. 1.

The importance of a knowledge of the factors affecting the moisture content of the wood lies in the fact that wood will shrink or expand with any change in the moisture content. Such shrinkage takes place across the grain and is greater for boards cut tangentially from a log than for quarter-sawed boards. The shrinkage with the reduction in moisture content in a direction parallel to the grain is negligible. On account of the great stiff-

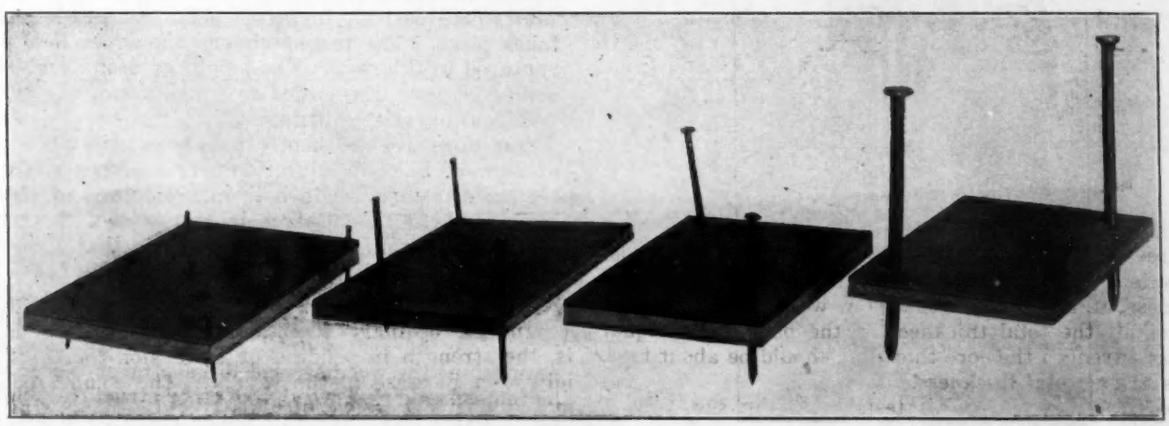


Fig. 2

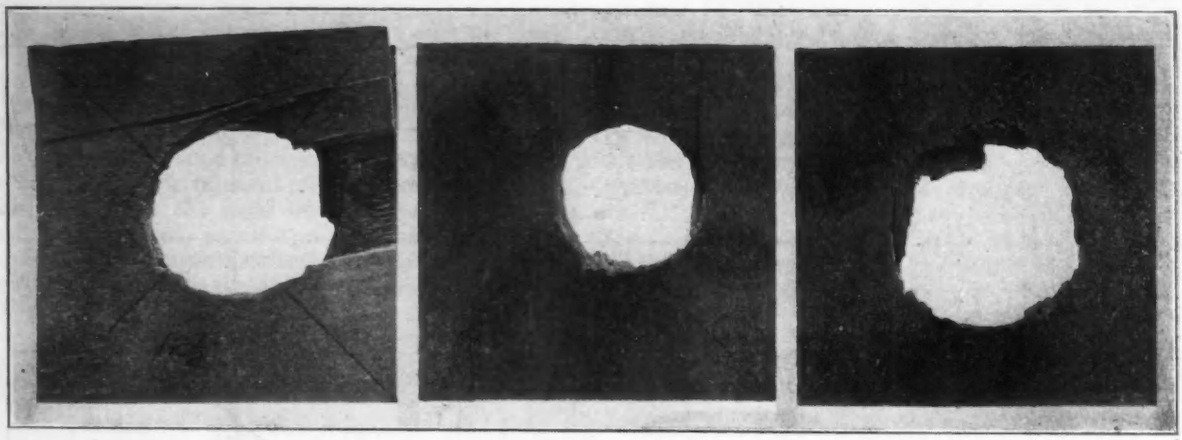


FIG. 4

ness of wood parallel to the fibers and its low shrinkage in this direction, the shrinkage of plywood resulting from a reduction in moisture content is very low. It is in fact only about as great as the shrinkage parallel to the grain of any ordinary wood. Where a board may be reduced in width by 0.2 in. the corresponding reduction in width of plywood will only be about 0.01 in. It is this marked difference in shrinkage between plywood and ordinary wood that makes it a superior material of construction for many purposes. Least possible shrinkage is desirable in automobile panels because an automobile may be exposed to extremes in atmospheric humidity and consequently the moisture content of the wood or plywood will undergo appreciable changes. Shrinkage may either cause checking of the panel which would mar the finish or it may cause loose joints, thereby introducing irritating noises in driving or even materially reducing the strength of the joint.

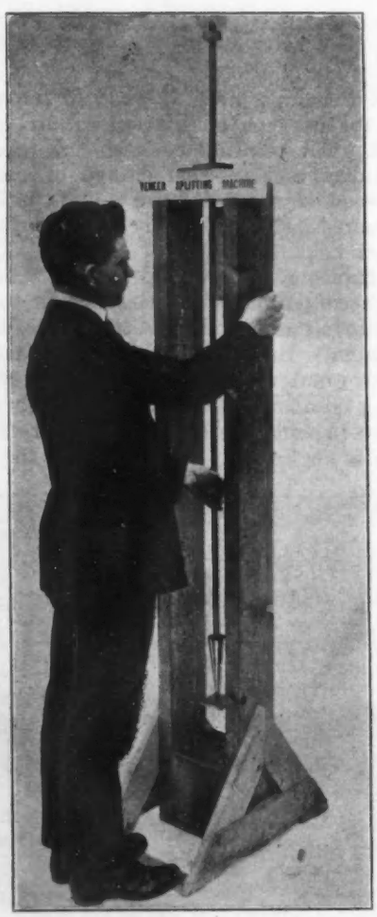


FIG. 3

In connection with the shrinkage of wood or plywood it should be borne in mind that no paint, varnish or enamel, irrespective of its advertised waterproof qualities, will prevent changes in moisture content of the wood it protects if the exposure to extreme humidities extends over a long period of time. Tests have shown that only a metallic coating like aluminum leaf is strictly impervious to moisture penetration.

One of the properties of ordinary wood that greatly limits its use for many purposes is its low resistance to forces tending to split the board. This is, of course, due to the relatively low strength of wood across the grain. By laminating and crossing the grain of successive laminations as in plywood this property is materially improved. The great resistance to spliting possessed by plywood is graphically illustrated in Fig. 2. The nails in the corners of the small panels were driven into the plain surface of the wood without any preliminary drilling. The sections are 5/16 in. thick. Even the largest nails caused no splitting of the plywood.

The machine shown in Fig. 3 was built at the Forest Products Laboratory to determine the relative resistances to splitting of plywood made of various species, thicknesses and combinations of plies. A test-specimen is shown suspended at the tip of the tool-steel spear. The height to which this spear was raised and allowed to fall is progressively increased until fracture by splitting takes place. The test-specimens shown in Fig. 4 were ruptured in this way. The height of drop at which failure takes place is recorded as a measure of ability of the specimen to resist splitting.

Questions are frequently asked regarding the ability of plywood to resist vibration. This property is of considerable importance in both automobiles and airplanes. Tests made at the research laboratories of the company with which I am associated have shown that plywood can be subjected to vibrations severe enough to cause weakening of the wood and yet no failure in the glue joint will take place. Specimens were subjected to several million repetitions of stress until an actual reduction in the strength of the wood seemed to have taken place. It will be remembered that wood, like other structural materials, particularly steel, will fail under repeated stresses that are much below those which cause failure in slow or static

loading. The tests were limited to plywood made by the company mentioned and the conclusions have still to be verified for various water-resistant glues.

Extensive shear tests made at the Forest Products Laboratory on plywood of different constructions have shown that while the initial failure occurs at a stress only slightly greater than the shear strength of ordinary wood, final or complete failure in shear is difficult to obtain on account of the tendency of the fibers to hold on in tension. The failure of ordinary wood in shear is sudden and complete, while that of plywood is progressive and prolonged. This property is somewhat analogous to the characteristic of steel described as toughness. A brittle metal will snap while a ductile or tough metal will yield and yet on account of the stretching imparted to it show no failure. Its ductility makes it a superior steel for many purposes. Plywood which is much tougher in shear than ordinary wood is likewise superior to wood.

Plywood Compared with Metals and Pulp Boards

In comparing the tensile strength of plywood with other materials used for automobiles such as pulp board, aluminum and steel, red gum was selected as a species because it is very extensively used in automobile construction and is of medium density and strength. The strength values given for this material in Table 2 were

TABLE 2—STRENGTH OF AUTOMOBILE MATERIALS

	Specific Gravity	Tensile Strength, lb. per sq. in. Parallel to Grain	Tensile Strength, lb. per sq. in. Perpendicular to Grain	Average	Tensile Strength per Unit of Weight, lb. per sq. in.
Three-ply wood	0.59	7,850	4,930	6,390	10,800
Pulp board	0.64	1,946	902	1,424	2,230
Rolled aluminum	2.70	.....	.....	19,450	7,200
Mild steel	7.85	.....	.....	60,000	7,650

taken from the Forest Products Laboratory figures listed in Table 1. The specific gravity given in the latter table is for over-dry weight. A moisture content of 9 per cent was assumed, which brings the specific gravity up to 0.59. It will be seen that the strength per unit of weight of the plywood is superior to that of the pulp board, aluminum or steel.

In addition to strength, an automobile material, especially if it is exposed in a large surface, must resist impact. If the surface is struck, it should show a minimum tendency toward receiving a permanent impression. Tests were made at our laboratories to compare the resistance to impact of steel and aluminum sheets of the usual thickness used in automobile bodies with three-ply wood of about the same weight. The device illustrated

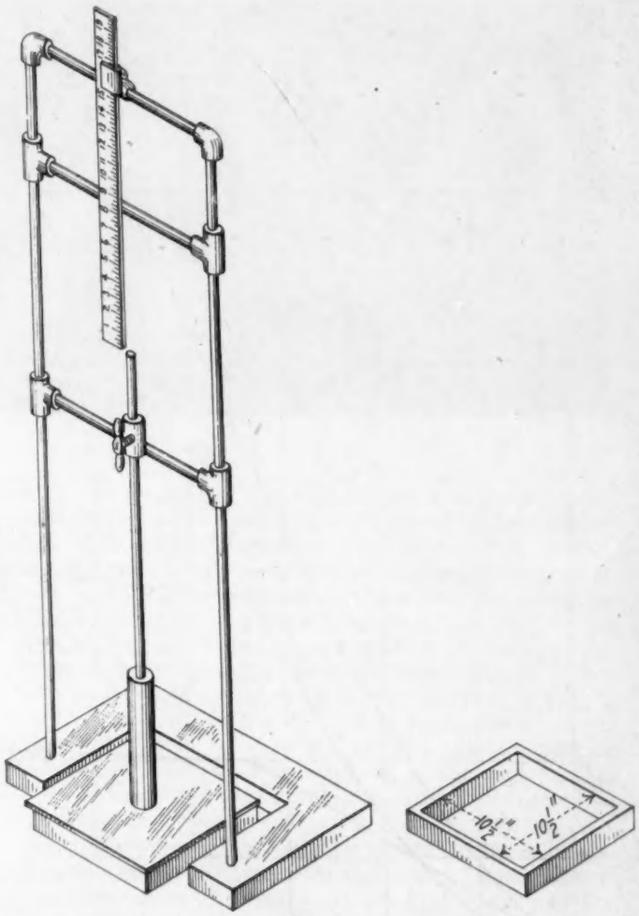


FIG. 5

in Fig. 5 was designed for this purpose. A panel was placed upon the surface of a frame 10½ in. square on the inside and a plunger weighing about 12½ lb. was allowed to drop from increasing heights upon the surface of this panel. The results of such impact blows upon panels of steel, aluminum, and three-ply red gum are shown in Fig. 6. It is apparent that the permanent set in the metal panels is very large, while with the exception of a slight dent in the outer surface and minute fractures of the fibers on the inner surface, no permanent deformation was caused in the plywood panel. The results of the test are given in Table 3. It will be seen that the energy imparted to the plywood panels was many times as great as that to the metal sheets. Whereas only one blow was necessary to produce a large dent

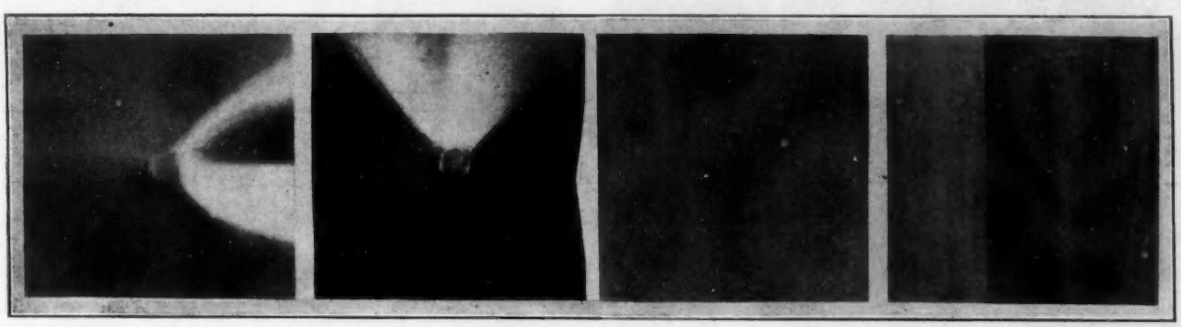


FIG. 6

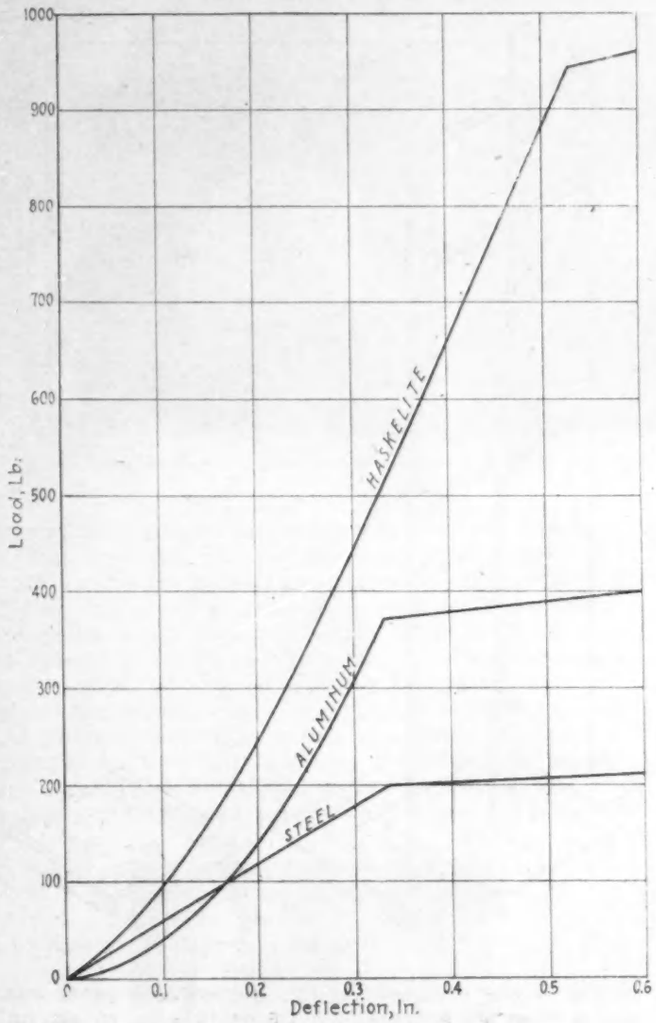


FIG. 7

in the metal sheets, the plywood was subjected to several drops of equal height and even then suffered no serious set or fracture. Under these severe conditions the plywood showed no further injury than slight surface depressions.

The results of slow static loading upon panels of plywood, steel, and aluminum of the same size are shown in Fig. 7. It will be seen that the load at which a material yielded or suffered a permanent set was very much higher for the plywood in both cases. The plywood was also stiffer as indicated by the slope of the curve.

Many erroneous ideas are current pertaining to the construction of plywood, which frequently result in creating an unfavorable impression of plywood as a material of construction. One airplane manufacturer, for example, was under the impression that to gain equal strength in the two directions parallel and perpendicular to the face grain, it was best to use four plies each of the same thickness running two in one direction and two at right angles to it. Experience has shown, and an analysis of the stresses introduced bears out, that such a construction of plywood must introduce considerable warping when undergoing moisture changes. The following rule may be adopted to govern the proper construction of plywood so as to minimize all tendency to warp:

TABLE 3—IMPACT TESTS ON AUTOMOBILE MATERIALS

Material	Weight, lb. per sq. ft.	Energy of Blows, ft.-lb.
Aluminum	0.91	16
Steel	1.21	16
Three-ply Haskelite	0.91	78
Five-ply Haskelite	1.16	151

> A panel must be made of an odd number of plies and for every ply on one side of the center there must be a corresponding ply on the opposite side at the same distance from the center, of the same thickness, and of the same species or one of about the same density, and having its grain running parallel to that of the first ply. The grain of successive plies should always cross at approximately 90 deg.

Even small deviations of this rule may cause warping in the case of large thin panels.

In making a selection of species it is usually only necessary to examine the density of the species to obtain information in regard to its properties. Hardness,

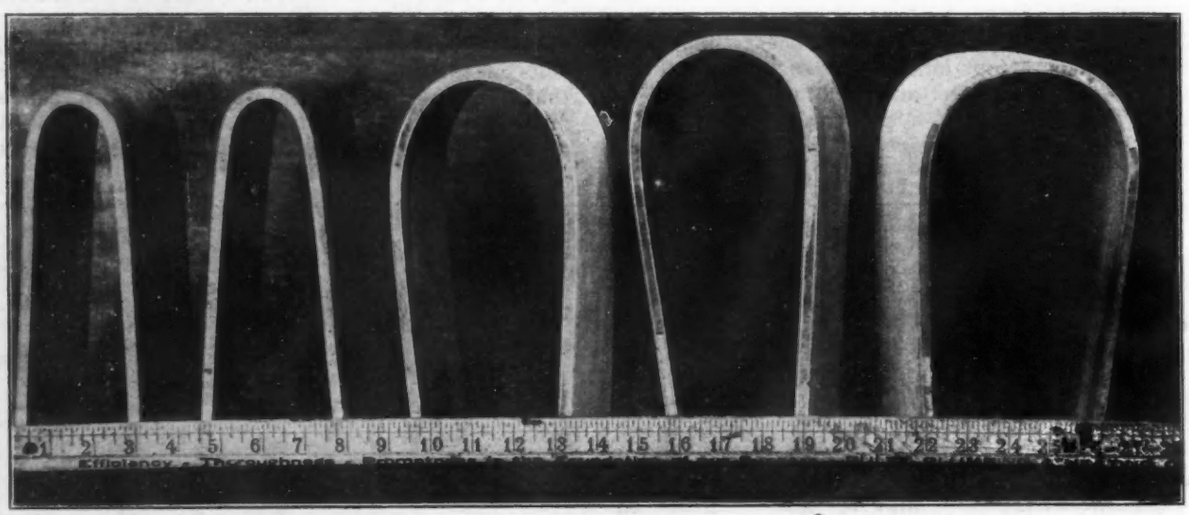


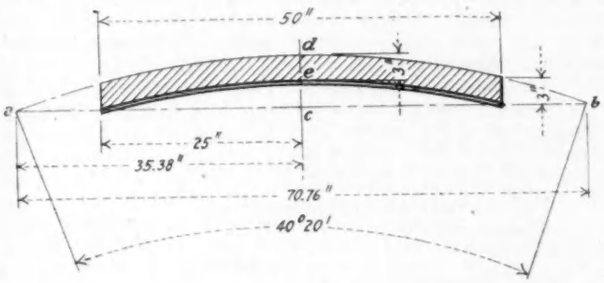
FIG. 8

strength, and stiffness are increased with increase in density.

Molding Plywood

The remarkable degree to which three-ply wood can be bent is illustrated in Fig. 8. The strips shown were originally flat. They were placed in boiling water for several hours until the wood fibers were thoroughly softened, then bent over a form and clamped in position until they were dry. Upon removing the clamp it was found that the specimen had assumed and retained the curvature of the form. The specimens were 5/16 in. thick and were bent with the face grain extending around the bend. Bending in simple curvature, as shown in the specimens of this figure, is a comparatively simple procedure.

It is when an attempt is made to bend plywood in compound curvature that great difficulty is experienced.



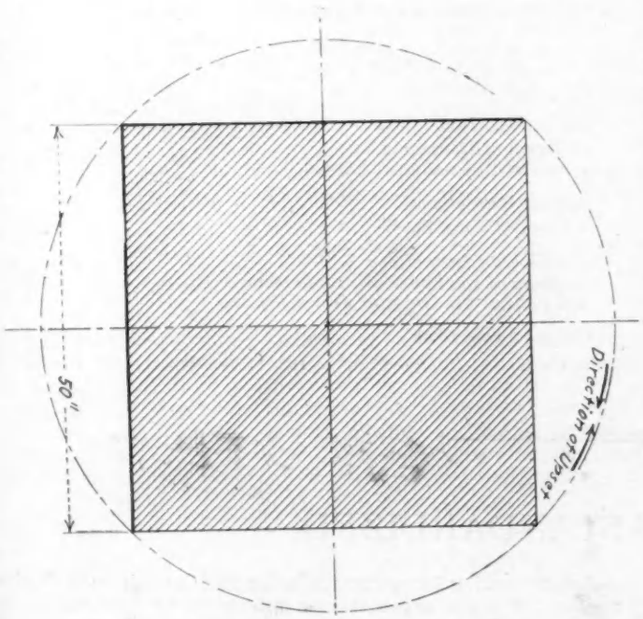


Fig. 9

In cases of this kind the wood must be upset. The meaning of this term is best understood by examination of the changes that take place in bending a wood felloe for a wagon wheel. The wood strip intended for this purpose is first softened by steaming and then bent around a form. Careful measurements have shown that the wood fibers on the circumference or outside circle suffer no elongation and that the change in the dimension all takes place due to a shortening of the other fibers. The magnitude of the shortening or upset of the wood fibers on the inner circumference is given by the difference in the length of this circumference and the outer circumference. This difference expressed in percentage of the outer circumference or original length is termed "per cent upset". It is, of course, evident that even in simple curvature of plywood the fibers on the inside of the bend are upset to a slight degree.

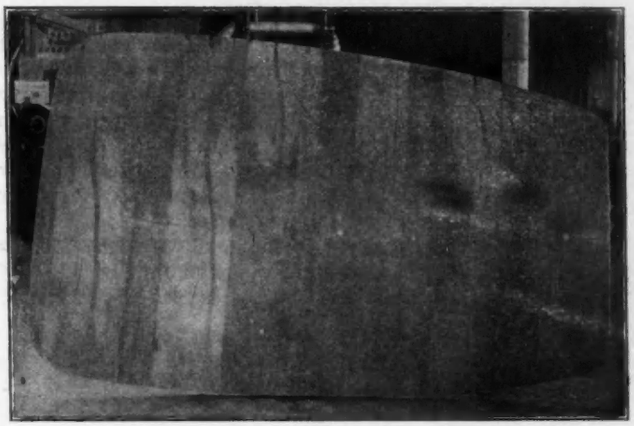


Fig. 10

Only in the case of compound curvature, however, must any appreciable upset be given to the material. This will be understood by referring to the diagram in Fig. 9. It will be assumed that a flat circular panel is available having a diameter equal to the arc *adb*. It will also be assumed that the panel is made of a material that is plastic in the sense that it can be upset but cannot be stretched. To make it conform to the spherical surface, its circumference will have to be shortened by a magnitude equal to the difference in the circumference of the two circles whose diameters are the chord *acb* and the arc *adb*. When this difference is expressed in percentage of the original length, it will be seen that for the particular spherical surface of Fig. 9, the fibers along the edge will suffer an upset of 1.5 per cent. A square section 50 in. on edge will be cut out of this spherical surface. The section illustrated conforms to the requirements of a typical motor-truck cab roof. The fibers near the corners are consequently upset 1.5 per cent. The magnitude of the upset at other points can be computed in a similar manner. The computation of upset for roofs of closed passenger cars is more difficult and complicated.

The advantage accruing from bending plywood to double curvature is well illustrated in Fig. 10 which

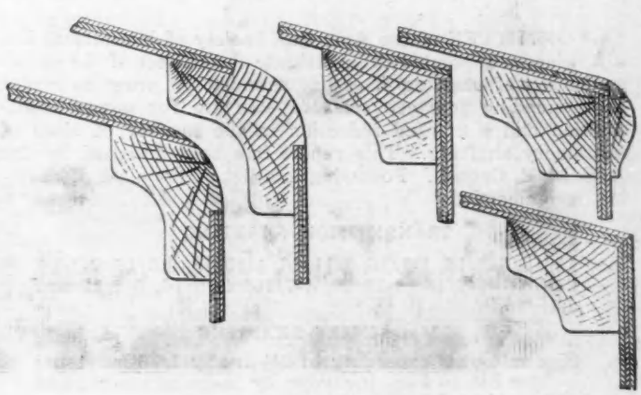


Fig. 11

shows in elevation a typical sedan roof made of plywood. Such a roof has supported the weight of five men without suffering any injury. To bend plywood to conform to the curvatures required in automobile roofs, it is necessary first to soften the fibers by wetting or steaming and then to press the flat three-ply panel in suitable dies. Means must be provided for drying the wood because it is only when the fibers are dried in the dies that the upset remains permanently.

Plywood can be fastened to the roof frame in various ways. Typical constructions are shown in Fig. 11. Of these the method illustrated at the left is probably the most common. Some manufacturers prefer to cover the joint with cloth to eliminate any possible showing of the joint.

The molding of plywood to compound curvature lends itself to many industrial applications. The magnitude of the upsetting that can be attained is, however, limited.

Such curvatures as those in the cowling of an automobile cannot be made of plywood. Extreme warped surfaces must continue to be made of steel or aluminum. In the present trend in design many of the compound curvatures in both body and roof can, however, be made of plywood.

DECORATIONS AWARDED THE ARMY AIR SERVICE

A TOTAL of 587 decorations has been awarded to the officers of the Army Air Service who served overseas. Details of the various decorations conferred and the number of each that was awarded are given in the accompanying table, which is taken from a recent issue of the Air Service News Letter.

	Number Awarded
American Decorations	
Medal of Honor	1
Distinguished Service Cross	235
Oak leaf clusters awarded with Distinguished Service Crosses	41
Distinguished Service Medal	17
British Decorations	
Companionship of the Order of the Bath	1
Companionship of the Order of St. Michael and St. George	8
Distinguished Service Order	1
Distinguished Flying Cross	20
Meritorious Service Medal	4
Military Medal	1
Belgian Decorations	
Commander of the Order of King Leopold	1
Officer of the Order of King Leopold	1
Knight of the Order of King Leopold	1
Officer of the Order of the Crown	1
Knight of the Order of the Crown	8
Croix de Guerre	1
French Decorations	
Commander of the Legion of Honor	3
Officer of the Legion of Honor	3
Knight of the Legion of Honor	17
Croix de Guerre with palm	64
Croix de Guerre with gilt star	10
Croix de Guerre with silver star	5
Croix de Guerre with bronze star	74
Medaille Militaire	5
Fourragere	8
Italian Decorations	
Gold Medal of Valor	1
Silver Medal of Valor	2
Officer of the Crown of Italy	1
Knight of the Crown of Italy	5
Italian War Cross	41
Roumanian Decorations	
Crown of Roumania	1
Star of Roumania with arms	1
Serbian Decorations	
Cross of King Peter	1
Montenegrin Decorations	
Officer of the Order of Pringe Danino	1
Knight of the Order of Pringe Danino	1
Chinese Decorations	1
Total	587

SHAFTING SIZES STANDARDIZED

A COMMITTEE of the American Society of Mechanical Engineers appointed to investigate the subject of the standardization of shafting sizes has submitted a progress report recommending fourteen sizes of shafting for power transmission and a marked reduction in the number of sizes of machinery shafting. This report has been accepted by the A. S. M. E. Council. Following is a list of the sizes of shafting recommended:

TRANSMISSION SHAFTING

15/16, 1-3/16, 1-7/16, 1-11/16, 1-15/16, 2-3/16, 2-7/16, 2-15/16, 3-7/16, 3-15/16, 4-7/16, 4-15/16, 5-7/16 and 5-15/16 in.

MACHINERY SHAFTING

Size intervals extending to 2½ in. by 1/16-in. steps; from 2½ to 4 in., inclusive, by ⅛-in. increases; and from 4 to 6 in. by ¼-in. steps.

Before making its recommendation the Committee invited a number of trade organizations interested in the matter to confer with it. Responses were received from the seven listed below.

American Hardware Manufacturers' Association
American Railway Engineering Association
American Supply & Machinery Manufacturers' Association
National Association of Manufacturers of the U. S. A.
National Association of Purchasing Agents
National Machine Tool Builders Association
Southern Supply & Machinery Dealers Association

As far as can be learned the standard sizes mentioned, which have been adopted by the American Society of Mechanical Engineers, have the unanimous approval of these associations.

APRIL COUNCIL MEETING

THE first of the series of meetings of the Council to be held in the West this year was convened on April 9 at the office of Councilor E. A. Johnston in Chicago, the following being present: First Vice-president J. G. Utz, Vice-presidents G. L. Martin, L. M. Ward and H. C. Buffington, and Councilors A. W. Scarratt, E. A. Johnston and E. A. De Waters

The Treasurer's report as of Jan. 31, 1920, and covering four months of the present fiscal year, showed that the total income of the Society in this period was $82,576.39, the expenses for the four months being $69,974.57, leaving a net unexpended income of $12,601.82.

One hundred and two applications for individual and affiliate membership and fifteen for student enrollment were approved. H. C. McIntyre was transferred from Associate to Member grade. In March ninety applications for membership were received, as compared with eighty-three in the same month of last year. On April 1, 1920, 4701 individual and affiliate members and students were enrolled in the membership of the Society, this being 589 more than were so enrolled on April 1, 1919. The resignations of Clark Thomson and K. Heindlhofer from membership in the Society were accepted. One feature of the session was the election of Ethel L. Bailey and Marie Luhring as Junior and Associate members of the Society respectively. The Constitution of the Society has permitted the election of women as members for several years but this was the first occasion upon which advantage was taken of this provision.

Appointments to the Standards Committee, with assignment to Division as indicated, were made as follows:

ROLLER BEARINGS SUB-DIVISION

B. H. Anibal	F. P. Hall, Jr.
A. K. Brumbaugh	Russell Huff
G. A. Carlisle	L. K. Snell
L. W. Close	H. C. Snow
D. Fergusson	F. A. Whitten

ELECTRIC TRANSPORTATION DIVISION
J. M. Breitenbach

ELECTRIC EQUIPMENT DIVISION
R. G. Thompson

ISOLATED ELECTRIC LIGHTING PLANT DIVISION
E. B. Newill

It was decided that a Division of the Standards Committee should be established for the purpose of considering such radiator parts and features as size and gage of overflow tubing, size of molding for frame jobs, manner of anchoring frames, size of studs and stud spacing, spacing of bolt-holes on cast-iron headers, size of inlet and outlet flanges, tests, tanks and depth of cores. From a general inquiry that has been made it appears that it will be advantageous to formulate standards for some of the elements mentioned above and a personnel for this purpose will be announced at an early date.

With reference to the work of the Electric Transportation Division, which has been started in an encouraging way, the Council took additional action, including the transfer of E. H. Remde from the Passenger Vehicle Subdivision to the Industrial Truck and Tractor Subdivision, appointing Karl Probst chairman of the Passenger Vehicle Subdivision, and J. M. Breitenbach chairman of the Industrial Truck and Tractor Subdivision, and C. E. Cochran a member of the Industrial Truck and Tractor Subdivision.

The following additional subjects were added to the program of work of the Standards Committee:

Tire Valves—Tire and Rim Division
Plywood—Aeronautic Division
Synchronizer Attachments—Aeronautic Division
Commutators—Electrical Equipment Division
Tractor Engine Fan Mountings—Tractor Division

The action of the Cleveland, Pennsylvania, Minneapolis and Mid-West Sections of the Society in the adoption of Constitution, By-Laws and Rules, was approved. These Sections are now on a standard basis with regard to these fundamental documents, inasmuch as they all have practically the same Constitution, By-Laws and Rules. The same thing applies to the Detroit and the Buffalo Sections, except that the By-Laws of the former are slightly different from those of the other Sections.

A report was received from Chairman H. L. Horning of the committee on the utilization in old and present engines of the more or less volatile fuels known as gasoline. This report was approved for publication, it being intended to serve as a guide in the consideration of means for the vaporization and distribution of fuel in automotive internal-combustion engines.

In connection with the current agitation with reference to the metric system with a view to its adoption in this country, the Council decided that the subject should be listed for discussion at the meeting of the Society to be held at Ottawa Beach on June 21, for the purpose of securing representative expressions of opinion, and not necessarily to take definite action at this time. It is hoped that the members of the Society will make a special study of the points involved in this matter, prior to the time of the meeting, so that the discussion may be properly effective.

Councilor F. M. Germane and Chairman Bachman of the Standards Committee were delegated to act as representatives of the Society at the Industrial Stability sessions of the American Academy of Political and Social Science held in Philadelphia on May 7 and 8.

OVER 1200 LANDING FIELDS LISTED IN THE UNITED STATES

THE Manufacturers Aircraft Association reports that there are more than 1200 landing fields in the United States. Approximately 10 per cent of these are permanent airdromes of the Army, Navy, Aerial Mail Service or commercial organizations. All of the States are represented in the list that has been compiled except West Virginia, which is the only State without any landing field. Illinois leads with 124 fields or 10.2 per cent of the total and is closely followed by Texas which has 117 fields or 9.6 per cent. From here the number drops to 66 which is the number of fields in Oklahoma, the number in the various other States decreasing more or less gradually to two fields in the District of Columbia. The details of the five leading States are given in the accompanying table.

	State air symbol	Number of fields	Per cent of total
Illinois	IL	124	10.2
Texas	TX	117	9.6
Oklahoma	OK	66	5.4
California	CA	64	5.3
New York	NY	57	4.7

The State air symbol referred to in the table is the designation mark assigned by the Air Service to each State and is displayed with the field number on each airdrome.—War Dept. News Bureau.

Discussion of Papers at the Annual Meeting

THE discussion of the papers presented at the recent Annual Meeting of the Society included written contributions submitted by members who were unable to be present and the remarks made at the meeting. In every case an effort has been made to have the authors of the several papers reply to the discussion, both oral and written, and these comments, where received, follow the discussions. For the convenience of the members, a brief abstract of each paper precedes the discussion, with a reference to the issue of THE JOURNAL in which the paper appeared, in case it is desired to refer to the complete text and illustrations.

TENDENCIES IN ENGINE DESIGN

BY L. H. POMEROY

WAR service demanded that gasoline engines be absolutely reliable in minor as well as major details of construction; lightness of construction was second in importance. The war scope of the gasoline engine was so wide that engineers were forced toward the solution of unexpected and unrealized problems and a vast amount of valuable data resulted. This information includes recent determination of the quantitative nature of the factors governing thermodynamic performance in respect to mean effective pressure, compression ratio and the effect of volumetric efficiency; mechanical performance in regard to mechanical efficiency and internal friction; and engine balancing. The problems of the past five years of intensive gasoline-engine experience, thus brought under critical survey for the first time, are discussed in the light of recent developments and a reexamination made of designers' existing practice to determine the trend of design regarding the obtaining of absolute mechanical efficiency; the application of modern views of gasoline engine thermodynamics; improvements in mechanical efficiency, engine balancing, carburetion and capacity to utilize low-grade fuels; the principles of light-engine design; and clean-cut design in general. [Printed in the January issue of THE JOURNAL]

THE DISCUSSION

CAPT. R. W. A. BREWER:—I have been here for three and a half years inspecting on behalf of the British Government Mechanical Transport Department, seeing exactly what you were doing and what you could do, and the remarks of Mr. Pomeroy to the effect that while being conducted over many American factories he has seen the vindication of principles he has held for many years in relation to cost of production; that by sheer manufacturing skill and enterprise work of the first quality is produced; that complex parts seem to have no terror for the production department; that any rational increase in the complexity of design does not appear to be a consideration in arriving at a desired result; and that the engineer is far less limited in attaining his ends in the United States than in Europe, are fully borne out by my own experience and by that of other inspectors. The point is, that we fully appreciate the very fine quality of work that you have been able to do in mass production here in America, by American methods. On our part, we have felt that we had to act with discretion and with knowledge of our business, so that we could cooperate with you and your production departments, adjusting the limits of accuracy to suit your methods, by which you were able to produce in quantity reasonably, without condemnation of parts that were perfectly satisfactory for their intended purpose. That is the crux of the whole situation. Where you want to produce by American quantity methods real good work that is good for the purpose for which it is made, it undoubtedly can be made the best in the world.

Mr. Pomeroy's paper deals with so many vital subjects that I shall refer to only one small section, to which I am devoting my entire attention, the question of handling liquid fuel in the manifold and the carbureter. It is very interesting to note the keenness of mind of the American engineer toward the problems involved.

The intake manifold has received less attention in proportion to its deserts than any other part of the engine. It is as vital to the performance of the engine as the carbureter or the magneto, and there is science behind them. Furthermore, the carbureter and magneto depend for their correct functioning upon the intake manifold; because, however good an ignition system may be, with a bad intake manifold it cannot function properly, and both are blamed for things for which they are not responsible.

I will at this moment draw to your attention certain vital points not fully realized and dependent one upon the other in the correct design of an intake manifold. At the 1913 Meeting of the Society on the Great Lakes, we discussed the intake manifold in a small way. I argued that the intake pipe was an unnecessary evil and should be abolished. That pipe has disappeared in the meantime; it has taken some years to eliminate it, but it has disappeared. The point was not fully realized at the time and I gave you no indication as to what I considered the proper way to manifold an engine; but I have since done much work along these lines. The trend of design is right, although slow. For an engine to function, a dry, cool, homogeneous mixture is required, distributed to the cylinders in equal quantities.

J. G. VINCENT:—I have been engaged in research to find out what the real advantage of the I-head engine is. This experience has given me much renewed interest in the L-head engine. Considering that the automobile engine operates at a very small percentage of its total output 95 or 98 per cent of the time and investigating the question deeply with an open mind, it is found that there is not the added efficiency in the overhead-valve engine that might be expected.

I have been astonished at some of the economy figures obtained from an improved L-head engine and make the prediction that during the next few years we will see a stronger tendency to retain or return to the conventional L-head design. In my opinion we will see many detail improvements brought about in this design and, in this connection, I mention the forged aluminum connecting-

rod, which has, I think, distinct possibilities. It is my belief that the tendency in design will be toward refinement of details and the development of new materials, rather than toward any radical departure to new types.

THOMAS S. KEMBLE:—Incompatibility between various requirements, such as turbulence and volumetric efficiency, as brought to light by recent progress, is not so serious as to be discouraging. We know, on the contrary, that the field for skill and ingenuity along the line of harmonizing these apparently contradictory factors grows with added knowledge. Furthermore, we have much that is of direct aid and contains few symptoms of incompatibility. Necessity for high-duty light-weight engines has resulted in a rearrangement of ideas regarding such matters as stroke-bore ratio and the use of aluminum. It has helped to bring about improved balancing arrangements and threatened old ideas of the ratio between stroke and length of connecting-rod. Reliability requirements have produced great improvements in ignition apparatus, valves, valve mechanism and various simple means for providing great stiffness without undue weight or expense. Allowable bearing pressures have been increased to such an extent that radical practice before the war is conservative now. At the same time bearing wear has been practically eliminated. Piston friction is being reduced and the piston-ring has been brought to a more reactional basis. We have proved in practice that narrow rings come to a bearing more quickly and form as good a seal as the old-style wide rings. Their life is less only in cases where the cylinder bore has been improperly finished. Piston-ring friction decreases in proportion as the width is reduced. The only limitation in this direction consists in the fact that rings must be wide enough to avoid excessive breakage in handling.

It seems to me, in view of these and other similar facts, that we may expect in this country automobile engines capable of delivering at least 1 hp. for every 5 lb. of engine weight. No sacrifice need be made of characteristics demanded of high-class automobile engines today, and the manufacturing cost need be no greater. Chassis and body design will follow perforce in the direction of light weight. The saving of gasoline and tires will be a great boon to the industry. It is undesirable to leave this subject without definitely recalling attention to the fact that possibilities for easy riding qualities are not a function of the car weight. They are a function of the ratio of sprung to unsprung weight, and the possibilities for reduction of weight are fully as promising in one as in the other. The public fancy is vicarious, demanding variety of combination and style. We shall therefore continue with various combinations of cylinders and more or less varied body design. There is nothing vicarious, however, in the harmonious combination of engineering and economic requirements which demand radical reduction in weight without the sacrifice of comfort or reliability. When this demand is thoroughly recognized and met, it will be found that the cost of production, instead of increasing, will show a marked decline.

G. W. KLINGER:—For six months I have been balancing crankshafts and flywheels, both statically and dynamically. We have obtained crankshafts from various automobile manufacturers throughout the country, to investigate and balance. A number of the shafts appear to be too weak; they are not rigid enough in that they whip, which naturally causes them to rotate around a curved axis. The flywheels seem too heavy for the crankshafts, which causes torsional vibration, or increases the vibration. Mr. Lanchester, of England, who has made a device to eliminate the torsional vibrations, has not taken into consideration the fact that a crankshaft and a flywheel must first be balanced both statically and dynamically before all torsional vibrations can be eliminated. It is absolutely essential, before using an anti-torsional-vibration device, to balance both statically and dynamically the crankshaft with the flywheel.

L. H. POMEROY:—I am particularly interested to learn that Mr. Vincent thinks as I do about the possibilities of the L-head engine, and I venture to say that during the next twelve months more people will think as we do. Captain Brewer's remarks are more in the nature of an addition to the paper than a criticism thereof; I fully appreciate and endorse his viewpoint.

Mr. Klinger's contribution is, however, very pertinent. I take this opportunity of stating, as one representing Mr. Lanchester in this country, that he certainly has no illusions upon the subject of the relative importance of static and dynamic balance. The work of the Lanchester crankshaft damper is to eliminate periodic torsional vibration. It does not and is not intended to have any effect upon static or running balance. It is, of course, highly probable that a crankshaft incorrectly balanced would be more liable to periodic torsional vibration than one correctly balanced, but the difference would be one of degree only. It should also be pointed out that it is by no means easy to obtain correct rotary balance in machines where only the ends of the crankshaft are supported, so that the crankshaft is free to whip when rotating at anything like a high speed. It has always seemed to me essential that the crankshaft should be kept rigidly in line before any balancing operations are carried out. It is also of interest to notice that the addition of crankshaft counterweights has a very considerable tendency to increase torsional vibration effects, unless the crankshaft is increased in diameter to allow for the effect of the heavy masses distributed along its length.

I am interested to learn Mr. Kemble's experience in respect to narrow piston rings, as it confirms my own.

ALUMINUM PISTON DESIGN

BY E. G. GUNN

THE two broad divisions of aluminum pistons from a thermal standpoint are those designed to conduct the heat from the head into the skirt and thence into the cylinder walls, and those designed to partly insulate the skirt from the heat of the piston head. Pistons of the first type seem logical for heavy-duty engines; those of the second type are better suited for passenger-car engines. The objections of wear, piston slap, excessive oil consumption and crankcase dilution are stated as being the same for aluminum as for cast-iron pistons; and these statements are amplified. Piston slap is next considered and, as this can be overcome by

using proper clearance, pistons of the second design tend to make this condition easier to meet. Many tests show that when too much oil is thrown into the cylinder bores, tight-fitting pistons and special rings will not completely overcome excessive oil consumption. Some details of the facts thus demonstrated are given and the conclusion is reached that more rapid wear follows crankcase dilution. [Printed in the December, 1919, issue of THE JOURNAL]

THE DISCUSION

J. E. DIAMOND:—I remarked when in France and England, both during the war and one time since, that manufacturers there are using much narrower rings both in iron and aluminum pistons than we use here. The French engineers attribute most of their success with alloy pistons, especially insofar as oil pumping is concerned, to the fact that they use narrow rings. I should judge most of those I saw to be but about half the width of our standard rings, with more of them being used; for example, in the 3¼-in. piston where we would use say three rings 3/16 in. thick, the French engineers specify four or five rings 3/32 in. thick and perhaps a little greater in depth than our own rings. I am more confident than ever that the aluminum-alloy piston is a sure thing. We may still have troubles with it but someone will solve these problems and soon we will find every car using alloy pistons. I think this piston will be very much along conventional lines yet embracing some special feature which will permit close fitting and at the same time allow the piston to yield when it would ordinarily seize.

H. M. CRANE:—The aluminum piston is of real value only where the question of heat conductivity is of great importance; that is in high-duty engines of large piston diameter. When it comes to motor-car engine work, the question of durability is of far greater importance than that of heat conductivity. Aluminum is not a good bearing metal. It will work in a cast-iron or a steel cylinder only as long as it is prevented from touching the wall. The first four-cylinder car in which we used aluminum pistons ran about 25,000 miles. We thought we had something fine; there was no perceptible wear on the cylinder walls and the pistons looked very good. We continued for another 15,000 miles and the car began to develop serious oil trouble. The car which had before been going 1500 to 2000 miles to a gallon began fouling spark-plugs and doing everything it should not have done. We found that the cylinders were tapered nearly ten thousandths from one end to the other. The pistons had finally reached a point where the upper land which had been cut way back began to touch and, being dry, as the upper land always is, it was the most beautiful lapping device you ever saw. We built twenty cars in Bayonne in 1912 with cast-iron pistons, rings and cylinders, and, to the best of my knowledge, a ring has never been changed in one of them since. I know of at least one that has run 80,000 miles; it has the same pistons and the same rings it started with. It is a better car on oil consumption now than it was at the end of the first 5000 miles. That is something that cannot be done with aluminum pistons from present knowledge.

I try to admire the French authorities for their efforts to control oil in the cylinders, but, from my experience, they do not know what real oil control in cylinders means. We had to redesign the aviation engine, as far as oiling is concerned, and in so doing we reduced the oil consumption one-half. In aviation engines we use narrow piston-rings; the engine comes rapidly down to a satisfactory bearing surface and we get tight pistons with a relatively small amount of running-in. Of course, the logical result is that the engine wears out more quickly, but we do not expect aviation engines to give the years of service that motor-car engines give. The motor car has to run about 10,000 miles before it is really in good running condition.

We were forced in production to make an aviation engine capable of wide-open running at the end of 4 hr. running-in, and without the help of any of the wear from dust, as with motor cars. In the case of our 300-hp engine, which had a 5½-in. bore, we attempted to do this with wide rings and the result was extremely unsatisfactory. We had to run it 8, 10 and 12 hr., and sometimes had to pull it down and replace rings. We changed to narrow rings and obviated the difficulty entirely. It is simply the usual engineering compromise. For motor-car work I am convinced that these so-called narrow rings are entirely wrong, being about half wide enough. I am running one of our big cars with wide rings, with about 0.008-in. clearance at the skirt, on a 4⅜-in. piston and with proper scraper rings. I brought the oil pressure up from 8 to 15 lb. without difficulty. There is practically no oil consumption whatever, in the sense that it causes any difficulty, as we are doing 1500 miles per gal. with a 563-cu. in. engine. I am convinced that the proper design of piston and ring is capable of giving satisfactory oil consumption, with very large piston clearances if you want them. Similarly with regard to piston-slap, which is largely caused by the piston being too short. On one of our earlier-model cars the pistons slapped badly with 0.005-in. clearance. We could not fit them much more closely than that and have them run. The result was that after 25,000 miles' running we had to replace them. In the next car we made we added 1 in. to the length of the piston, and quadrupled the length of the service of the car. I think that this shows almost conclusively that there are other considerations about piston design than that of what material to use in making them.

A. L. CLAYDEN:—What about the heat-treatment Mr. Pomeroy has given to alloys and the nature of the alloys he has treated? He stated, I believe, that he always gave pistons a normalizing treatment.

L. H. POMEROY:—The heat-treatment to which Mr. Clayden refers is that recommended by the firm which developed the Ricardo slipper piston. In pistons of that type there are two cylinders connected by webs at right angles to the line of cylinder bores and parallel to the cylinder axis. In sand castings it is found that certain contraction strains are produced so that, unless these are removed, it becomes a process of trial and error before the minimum running clearances can be obtained. It is found that by immersing these in oil at a temperature of 250 to 300 deg. cent. before finishing machining, these internal strains are removed so that it is possible to work to definite clearances. The aluminum alloy used in these pistons is a straight 12 per cent copper-aluminum alloy whose one recommendation compared to other alloys is the extreme satisfaction it has given.

MR. CRANE:—The pistons that developed trouble with the upper land started with 0.030-in. diametral clearance on the upper lands before we began running. The trouble was caused by the aluminum gradually wearing at the center of the piston, and thus allowing the upper end of the piston to cock over; we had plenty of clearance to start with.

As for the difference between wide and narrow rings, this appears to be largely a question of lubrication. I think that a really gas-tight piston-ring does not have a thoroughly-lubricated bearing surface; there is always a certain amount of metal contact. Probably it would not

be tight on the very short length of bearing it has, unless it had almost a metal contact. The result is that the wider ring does not wear as fast as the narrower ring, even if the unit pressure is exactly the same. This, I think, is because the wide ring establishes a more complete oil-film than the narrower ring establishes. Furthermore, the wider ring rides over the irregularities in the cylinder to a far greater extent than the very narrow ring, which again raises the question of metal contact that brings the rings down quickly to a good bearing surface. After they have reached a good bearing surface, there is not the same difference in the rate of wear between the two. But in beginning to run a new engine with new rings there is no doubt that the narrow ring will run-in at least three times more quickly than the wide ring. On an engine running at high mean effective pressure, which means high cylinder pressure, the narrow ring is far safer because nowhere near as likely to leak at the start.

E. G. GUNN:—I am inclined to agree with Mr. Diamond that we can use narrower rings than we are now using. Rings ⅛ in. wide on a 3¼-in. piston seem to be satisfactory. I also agree with him that the aluminum piston has great merit. I think the wear that Mr. Crane mentions is not due entirely to aluminum. With cast-iron pistons cylinders are often found to be badly worn and other cylinders scarcely worn at all. We also find some engines in the same run of production that show twice as much wear in 10,000 miles as others, and it is rather difficult to determine exactly the cause of the extra wear. When running competitive tests, I have found that there is not much difference in cylinder wear between cast-iron and aluminum pistons. In some cases with aluminum pistons the cylinder wear has been considerably less. Of course, the oiling system and, what is more important, the quick heating of the mixture play very important parts.

In running a great many tests on the same engine I have found that unless the piston-pin is too near the top of the piston, adding as much as 2½ in. to the skirt of the piston, the length of the piston had no effect on piston-slap. The experiments were conducted very carefully and checked a number of times to avoid error. However, if the piston-pin is too close to the top of the piston, the effect is worse than it is with cast-iron pistons, on account of the high heat conductivity. This makes it necessary to have a greater clearance on the diameter at the piston-pin.

NEEDS IN ENGINE DESIGN

BY F. H. TREGO

THE author advocates the use of the fragile aluminum crankcase as a spacer, running crankshaft bearing bolts clear through the crankcase and the cylinder base, so tieing the bearings firmly to the cast-iron cylinder-block and using the through-bolts also as holding-down studs for the cylinders. The results of experiments on six-cylinder engines with reference to the satisfactory utilization of engine fuel now on the market are then presented. The problem is how to carry the fuel mixture in a proper gaseous state from the carbureter into the cylinder without having the fuel deposited out meanwhile. The power developed at engine speeds of 400 to 2800 r.p.m., with and without hot air applied to the carbureter, is tabulated, the proper location of the intake manifold is discussed, and the necessary features of a satisfactory engine to utilize present-day fuel are summarized.—[Printed in the January issue of THE JOURNAL.]

THE DISCUSSION

THOMAS S. KEMBLE:—I am constrained to take exception to Mr. Trego's deductions regarding the practice of running crankshaft bearing bolts clear through the crankcase and cylinder base and using them as holding-down studs for the cylinders. This practice may serve to reinforce a fragile crankcase, but it often causes distortion and is not at all necessary in connection with a properly-designed crankcase. If the aluminum crankcase is extended to form the water-jackets as in some of the best aviation engine designs, through-bolts are out of the question. In four years' experience with high-duty aviation engines where through-bolts were not used, I have not observed a single instance in which the crankshaft bearings were adversely affected. Some of the earlier engines with individual cylinders developed trouble in the crankcase deck due to lack of rigidity, but this was completely remedied by the addition of very light inexpensive ribbing.

In the matter of heat application to improve distribution and smooth running, we are still unable to avoid some reduction of volumetric efficiency. Exhaust heat properly applied has decided advantages over the old-style water-jacket and hot-air intake. Improved operation with early closing intake valves can be ascribed to the elimination of "blow back" into the manifold at low speeds.

Mr. Trego's summing-up certainly is another indication of the general situation that we are unable to avoid reduction of volumetric efficiency. Progress along this line has not kept pace with requirements and perfection is not yet in sight.

H. C. GIBSON:—The attention Mr. Trego has called to the advantage of through-bolts, tieing the crankshaft bearings to the cylinders, is particularly interesting. I am sure that for all classes of engine the chiefs of production departments will find great advantage and will readily cooperate with engineers in the general introduction of this direct method of resisting those major engine strains through dependable economical steel rods, thus placing castings, which are always of uncertain dependability, under compression only. It is a comfortable thought of proved value in practice, and should be carried to the extent of holding down removable cylinder-heads by the same bolts.

Mr. Trego's paper and mine are surprisingly opposed in our analyses of engine needs regarding fuel; hence I must suggest some reasons for the astonishing results of tests he gives and for one of his recommendations which appears undesirable. Taking the statement of the test of the three-passenger car, I note that its speed

was reduced from 25 to 8 m.p.h. over the hill-top when hot air was fed to the carburter, no other change of condition having been made. I suggest that if the carbureter were adjustable and had been adjusted coincidently with the application of hot air, an economy of gasoline and at least equivalent speed would have resulted. It is worse than useless to turn on hot air to a carbureter set for cold air, because the heat vaporizes more of the fuel, enriching the mixture far beyond the proportion which will give maximum power. This seems to have happened in the case Mr. Trego has cited. There is no other reason for the results, which are contrary to my experience. Even excessive temperature of the air could not be blamed if adjustment were neglected. Will the author please state the temperature used?

Mr. Trego is evidently strongly in favor of "volumetric efficiency per stroke." Granting that hot air or manifold mixture heaters do reduce such efficiency somewhat, I fail to grasp the value of further reduction by adopting his recommendations of small sizes of intake passages. Logic seems to indicate that, having caused vaporization through heat, we do not need the high speeds of intake gases which were universally used in the trade prior to the date when makers, finding such methods ineffective, undertook to add at least some heat to intake gases. Small intake passages cause loss of volumetric efficiency; they are unnecessary and detrimental when the gases are properly heated.

The inlet manifold being entirely water-jacketed, as Mr. Trego states, no doubt causes the peculiar happenings recorded. My company has lately developed the fact that 5 cc. of the lower-boiling-point fraction of a common engine gasoline, held at 180 deg. fahr., required 5 min. for complete evaporation; while 5 cc. of the higher fraction required 6 hr. It is clear from this that water-jacketed inlet manifolds should be avoided. Such jacketing will nullify or offset any effort made to evaporate gasoline prior to entering the manifold, and will destroy the value of test records of heating methods.

Mr. Trego brings out a valuable point in recommending earlier closing of the inlet port when using heat. Later closing was necessary to take advantage of the cylinder-filling ability of a column of gases traveling at high velocity; with decreased velocity earlier closing is an advantage. The application of heat to the mixture after it leaves the carbureter is a correct recommendation. I would add that it is also of advantage to use heated air of constant temperature.

F. H. TREGO:—I appreciate that running the crankshaft bearing bolts clear through is impractical when using the water-jackets and crankcase in one piece; but this makes a very unhandy piece in the manufacture of commercial engines, and my paper does not refer to the design of aeronautic engines.

The principal effect of the long bolts for the bearings is shown in the slight wear of the bearings as against the wear when the bearings are held in the crankcase only, and of course the wear will be less if the crankcase is heavy and heavily ribbed; but we are all anxious to get light weight in our passenger-car engines and the running through of the bearing bolts allows a very light crankcase, at the same time assuring rigidity and long wear on the bearings. No distortion can take place through the use of the bolts if the vertical ribs at each bearing boss are extended to the end of this boss, for then the boss with its ribs becomes a simple spacer and should withstand the crushing strain of the bolts. Running 100 hr. with a dynamometer, at speeds from 1000 to 3000 r.p.m. while making power curves, developed no bearing wear; and this should be equal to about 40,000 miles at 40 m.p.h.

The application of heat after leaving the carbureter, even to the extent to which we have carried it, loses but 4 hp. on the dynamometer at 2600 r.p.m, but on the road the car was even faster than before and the acceleration was much improved, so that although a slight loss of 6 per cent was indicated on the test stand it did not show up on the road.

I object to holding down the cylinder-heads with the crankshaft bearing bolts, on account of their extreme length if used for this purpose. The stretching of the bolts, unless they are very heavy, would be the objection to this practice.

On the speed and hill-climbing tests made with and without hot air in the carbureter, we adjusted the carbureter in each case for maximum speed and acceleration, so I deduced that the lack of heat after leaving the carbureter allowed condensation in the intake passages between there and the cylinders, thus causing the loading which of course killed the pulling ability of the engine on the grade.

Regarding the size of intake passages, we experimented with 1½, 1-7/16, 1⅜ and 1¼-in. sizes, finding that the 1⅜-in. size gave the best all-around results and did not fall below 65 hp. on the 3½ by 5-in., 6-cylinder, L-head-type engine. Mr. Gibson may not call 1⅜ in. "small," and therein would lie his disagreement with me on this matter, but our object was to keep the velocity as high as possible without decreasing volumetric efficiency.

I agree with Mr. Gibson in the statement that we would not need small intake passages if the gases were properly heated; but thus far I have been unable to obtain sufficient heat to reach such a condition. Our engines run exceptionally cool, but we find a jerking at about 10 m.p.h. with light throttle, unless the heat is applied, and even though the entire manifold, if at least as small as 1⅜ in., is within the water-jacket except along one side, which is exposed to the exhaust gases.

The early closing of the intake valve is only recommended in six-cylinder engines when one carbureter is used. Closing the intake much later than 15 deg. is perfectly practical on a four-cylinder engine, or on a six-cylinder engine if a carbureter is used for each three of the cylinders, where there was no overlapping of the suction stroke that would interfere with the filling of the cylinders.

Referring to the size of intake passages, if the spark-plug is placed in such a position that the flame propagation has an equal distance to travel in all directions, the compression can be carried higher and we thus get the stronger suction which will pass the required amount of gas even though the intake passage is small. The compression of 23.2 per cent of the total volume is carried on both the L-head and the I-head engines; no hammering takes place in the L-head engines, such as would be the case if the spark-plug were carried over one of the valves. I would therefore recommend the use of high compression, proper location of the spark-plug, smaller intake passages and the application of all possible heat after leaving the carbureter.

A STEAM AUTOMOTIVE SYSTEM

BY L. L. SCOTT

IT is stated that the general performance of the steam-propelled automobile has never been equalled by that of the most highly-developed multiple-cylinder gasoline cars and that it is significant that no innovation in the gasoline car has yet been able to give steam-car performance. This led to an effort to remove the troublesome features of the steam car, rather than to complicate the gasoline car further by attempting to make it duplicate steam-car performance. The paper describes in detail the steam automotive system developed by the author and E. C. Newcomb, including the boiler; the combustion system and its control; the engine and the condensing system. [Printed in the November. 1919, issue of THE JOURNAL]

THE DISCUSSION

A MEMBER:—Regarding the nozzle, what pressure is used in atomizing the oil?

L. L. SCOTT:—We use 35-lb. pressure; the oil will atomize at 10 lb.

A MEMBER:—What diameter has the hole at the end of the nozzle?

MR. SCOTT:—That depends upon the quantity of fuel we wish to burn. We have burned as high as 70 lb. per hr. In that case, we use about a 0.04-in. nozzle at 35-lb. pressure.

E. F. ANDREWS:—Is there not an objection to using an electric motor to drive the water-pump of a steam automobile? The pump requires considerable power and to transform from mechanical into electrical energy and back again is rather an inefficient means of driving. There are great advantages, unquestionably, in using an electric motor to drive the pump, but to what extent do the pump-driving losses offset these advantages?

MR. SCOTT:—The electric drive is equally as efficient as a direct drive from the engine, for several reasons. One is that in driving water-pumps from the engine energy is being wasted in pumping water that is by-passed, because the engine is running all of the time the car is running and water is being pumped. But with the electric drive, when the motor is running all of the water being pumped is used; none of it is by-passed. Further, the electric motor for driving the water-pump, the fuel-pump and the air-blower, in the normal-sized car, takes about 0.75 hp. The dynamo and the motor each have a compound winding. The series field of the motor and dynamo are connected in series. When the fire is on and the car is running, the dynamo furnishes current direct to the motor; there is no loss through a storage battery. When the motor cuts off automatically, due to high steam pressure, the dynamo output is automatically cut down to a current suitable for charging the storage battery because the series field is cut out. The electrical unit in this system is very little, if any, larger than the ordinary dynamo and motor used on a gasoline car.

A MEMBER:—Have you ever used any other means than the spark-plug for igniting the oil, such as winding leather with nickel wire, bringing it to an incandescent heat?

MR. SCOTT:—No. We found the common spark-plug very satisfactory and have never had occasion to use anything else.

A MEMBER:—Have you tried that to avoid sooting trouble?

MR. SCOTT:—We have no sooting trouble.

B. F. TILLSON:—I would like to ask Mr. Scott to contribute for publication in the *Transactions* some more complete engineering tests, in regard to boiler and engine efficiencies and the temperature of the gases leaving this boiler. These would form a basis that could be used in a rough-and-ready manner in checking against too high efficiencies. There have been steam cars in the past in which the engine efficiencies, as noted in the discussion in the *Transactions*, did not check up, or the boiler efficiencies failed to check up with the temperature of the leaving gases; and there is an inevitable amount of heat lost. An idea of the fuel oil consumption per boiler horsepower would be of interest. I understood that the rating of the boiler is 500 lb. of steam per hr., from and at 212 deg. fahr., which would be a 14.5-hp. rating of the boiler. Mr. Scott said that 72 sq. ft. was the surface of the boiler tubes.

How heavy an oil has been used successfully by a mechanical atomizing burner without difficulty in clogging the burner?

W. C. KEYS:—What is the composition of this tube? It is nickel steel, I take it.

C. W. SPICER:—The paper explains what happens if too large a proportion of fuel is supplied; but what happens if the supply of fuel is inadequate? There are extreme conditions; for instance, when a doctor is making calls about town on a cold windy day, his car stands out in a blizzard for an hour or more, he travels perhaps 5 min. to the next call and then the car stands another hour. The fuel required to make up for loss from radiation might be considerable when no corresponding amount of steam was required. How do the automatic features meet that condition.

HENRI G. CHATAIN:—I agree with Mr. Scott's statements to such an extent that constructive criticism becomes difficult because it bears largely upon details. I believe Mr. Newcomb first worked along the line indicated in about 1900, and did not recommend the system of direct proportioning of both water and fuel control as advocated at present. Do these proportions remain constant in actual operation? If not, how can the disproportioning be corrected so as to preclude the possibility of a too cold boiler, considering that the amount of water evaporated per square foot is not, throughout the range of operations, proportional to the fuel burned? With the system of parallel control of water and steam, is the degree of superheat maintained reasonably well?

Has Mr. Scott made investigations, which would be at all conclusive, leading to the determination of what percentage of the boiler tube is filled with water, what percentage contains steam and whether this varies at different rates of output? To my knowledge none of the earlier investigators attempted this determination, but it would be an excellent thing to know, so that in designing a boiler one could preclude the possibility of having the influence of gravity bring water down into the steam part of the coil, thereby raising the pressure when it is not wanted.

In the particular boiler just described, what is the cubic space of the combustion chamber, or has the cubic space required to properly burn a unit of fuel been determined? In the early days this space varied considerably, appar-

ently according to the fancy of the designer, but today there seems to be a general trend toward making this space considerably larger.

Has the make-and-break plug such as was formerly manufactured by the Bosch company and used with the Honold system been tried? It seems to me that this type of plug offers qualifications for this particular class of work which would be far superior to the high-tension variety. We have used these plugs to a considerable extent in internal-combustion engines and find that they are much more reliable under sooty conditions than the high-tension plug. Their inability to function at extreme high speeds and the excessive wear of both the "hammer" and "anvil" were their only faults. Used for the ignition of fuel in a steam automotive system, these faults would not be manifest and it would appear that their qualifications to work under sooty conditions would make their use highly desirable.

Summing up many tests which we have made, we find that the maximum evaporation per pound of fuel is from 13 to 13½ lb. and this was obtained when an evaporation of approximately 7½ lb. per sq. ft. of heating surface was effected. A superheat of 100 to 200 deg. fahr. was maintained. When the evaporation was forced beyond this point, the pounds of water evaporated per pound of fuel fell below 13. These results, which no doubt Mr. Scott has attained or even improved upon, when considered in conjunction with his statement of a brake horsepower for 12 lb. of water, show that a brake-horsepower-hour can be obtained with the steam automotive system for something less than 1 lb. of fuel. This fact, considered with the better efficiency of the steam engine at fractional loads, makes the system compare favorably with the best gasoline-engine practice.

MR. SCOTT:—In regard to boiler and engine tests, it will be out of the question to go into detail more than to say that in our boiler the efficiency varies from 75 to 85 per cent, under varying loads and conditions, and the steam consumption of the engine varies from 12 to 15 lb. per hp.hr. The temperature of the gases, the stack temperature, varies from 250 to 300 deg. as was stated.

Regarding the gravity of the oil fuel, while we have made tests in our laboratory on fuel oil and gas oil, we have never used those in the car; we have used only commercial kerosene.

The question about burner clogging evidently refers to the small fuel nozzle. Where the fuel is properly screened, we have no more trouble in that respect than with the ordinary carbureter. The opening is equally as large as that in the carbureter and it has given us no trouble.

With regard to the analysis of the tubing, we have used ordinary 3½ per cent nickel tubing. We do not know that it is any better than ordinary tubing. As I have stated, we have tried boiler coils in which the inner boiler coil was calorized, by a treatment developed by the General Electric Co. for the purpose of preventing oxidation at high temperatures. The question as to whether that is needed is still undetermined. If so, the cost is very low.

In reference to the fuel-water ratio, we have the fuel slightly in excess of the water. The ratio in our boiler varies between 1 to 10 and 1 to 13. We run the fuel slightly in excess of the water which, under extremely heavy loads, will cause the temperature to sometimes reach 800 deg. At this time the fuel is automatically cut off and the water continues to be pumped into the Our steam pressure and temperature, as a whole, is very steady and holds very well. Under light driving conditions when starting the boiler from cold, the steam temperature will probably be 500 deg. fahr.; after 5-boiler, providing the steam pressure is below normal. min. running it will get up to 650, 700 or 750 deg. and stay there. Under very heavy loads, it will sometimes get as high as 800 deg. and cut off. We have no trouble with steam at this temperature. As far as lubrication trouble is concerned we use deflocculated graphite, and our engine is a poppet-valve type, which is suitable for high temperature.

Mr. Newcomb worked intermittently on the steam automobile from 1900 to 1908. I have never heard Mr. Newcomb say that he did not advocate the system that we are using today. This system, or idea, of pumping water and fuel in definite quantitative relation was a fundamental idea of Mr. Newcomb's. We have applied it in a different way; that is, we have an electric control and an electric drive for the fuel and water-pumps.

We have never experienced any trouble in having too cold a boiler; if the fuel line is stopped up, the fuel and water ratio will change and the steam temperature will be lowered. With this system of control the temperature of the steam remains within 100 deg.; under ordinary driving conditions, it will hold very closely within 20 deg.

Referring to the portion of the boiler tube that is filled with water, I have never experimented with this. From what I learned from Mr. Newcomb I would say the first and second outer coils, referring to the illustration in the paper, are filled with water; the third is the vaporizing coil and a part of the fourth is the super-heating coil. The thing that I want to emphasize particularly concerning a fire of the atomized type is the size of the combustion chamber. The point was raised whether there is any definite size or figure. With a fire of the atomized type it is necessary to have a considerably larger space in which to burn the fuel than with a fire of the vaporized type, which has been on all automobiles of the past. The reason is that with the atomized type of fire the fuel is ultimately vaporized in suspension.

As to the flow of water by gravity from one coil to another, this is prevented by the boiler connections. The water enters the bottom of the outside coil and flows upward to the second coil, etc.

We have not tried the make-and-break spark-plug for the reason that we found the jump spark to be perfectly satisfactory and were satisfied to let well enough alone. It is not necessary to have any tight joints in a spark-plug in this system, as in the case of the gas engine, because we have no pressures to deal with; the spark gap can be considerably larger, because we are not working against any pressure. We formerly had sooting trouble, but overcame it in the way which has already been completely described.

It is possible to evaporate 13½ lb. of water with 1 lb. of fuel and get a superheat of 100 to 200 deg. fahr. When we overload the boiler or force it beyond its normal working condition, the ratio may change to as low as 1 lb. of fuel to 10 lb. of water. This ratio will change slightly according to different loads, but the change is not enough to affect the situation seriously in any way so far as we have been able to learn.

AUTOMOBILE BODY DESIGN

BY WILLIAM BREWSTER

THE author first considers the style and arrangement of the seats, the position of the rear axle as affecting the rear kick-up in the chassis frame, and the position of the rear wheels as determining the distance from the back of the front seat to a point where the curve of the rear fender cuts across the top edge of the chassis frame. The location of the driver's seat and of the steering-wheel are next considered, the discussion then passing to the requirements that affect the height of the body, the width of the rear seat, and the general shape. The evolution of the windshield is reviewed and present practice stated. Structural changes are then considered in relation to the artistic requirements, as regards the various effects obtained by varying the size or location of such details as windows, doors, moldings, panels, pillars, belt lines, etc., and the general lines necessary to produce an effect in keeping with the character of the car. The design of the wings or fenders, the weight, producing effects of light construction, and the use of aluminum are also considered, the conclusion reached being that the design of the highest type of automobile body should always be based primarily upon a high degree of practicability. [Printed in the April issue of THE JOURNAL.]

THE DISCUSSION

H. M. CRANE:—I agree with Mr. Brewster as to the impossibility of a satisfactory closed-body construction on airplane lines. There is no question that, for a given amount of strength, a very flexible construction is undoubtedly the lightest. On the other hand, in my opinion, a body requiring the use of glass, operative doors and similar features, can never be made flexible; that being the case, it must be designed for stiffness. Under such conditions, the extreme lightness of the construction used in airplanes cannot be worked out. All engineers engaged in engine design know that most of the disappointment with high-grade steels came from the fact that there were very few places in automobile engines where they could really take advantage of the possibilities of such steels, because a section had to be designed primarily to be stiff, and not necessarily for ultimate strength. This applies even more to bodies, and with the great increase in closed bodies it has been very interesting to see the spread to one company after another of a really proper design of chassis frame.

The chassis frame with 3 or 4-in. side-rails was amply strong to carry any load put upon it, years ago and also today, but is utterly out of the question with a closed body mounted upon it. In fact, the body builder was forced to add 100 to 150 lb. to the body to make it work at all and compensate for the 25 lb. the chassis builder left out.

AUSTIN M. WOLF:—No mention has been made of the necessity of co-relation between the body and the fenders, aprons, windshield, wheels, as in the disk type, and the top of open cars. It is very essential that the design between all these parts be in harmony with the body lines, or their effect and beauty will be nullified. We often find that the curves or straight lines in the side view of a fender, particularly the front, clash with the general line design of the body and hood. In a similar way the use of disk wheels, from an artistic point of view, is dependent upon the balance between the circular surface which they present and the surface presented by the hood, body side and side splasher. These masses usually harmonize best in a low-hung car.

It is becoming gradually apparent that more attention is being paid to the top design of the moderate-priced car than heretofore. The top when up, due to its raised position, presents an accentuated mass and the necessity for harmonious design is extremely important.

Very often a chassis is designed simply from the chassis engineer's point of view, and no thought is given to the body and the mounting of the other units which the word "body" must also broadly convey. It is my opinion that more thought can be given to the original layout, particularly to the frame construction, if we consider the particular body which we wish to use. At the same time, a great deal of weight can be saved by suitable frame design in allowing less overhang for the body sills and providing better support for them.

It is unsightly to see a short body mounted on a long frame in which the rear goose-necks, which at their best lack any semblance of beauty, project an undue amount. In this connection we have the advantage of using cross rear springs or the cantilever type, which assist in making a presentable rear end. Too little attention has been paid to this part of the car.

With cantilever springs as used by Rolls-Royce and its many followers, the springs lie outside the sides of the frame. It is impossible to use such a chassis construction with a Cunningham type of body without running-boards, as the springs would be exposed; assuming, of course, that an extremely wide body and sill are not used to bring the body side beyond the outside edge of the spring. Due to such inherent limitations of a particular chassis construction, and the above is but one example, it is evident that the various types of bodies should be considered before the final frame construction, spring mounting, etc., are decided upon.

With reference to the Rolls-Royce type of cantilever spring, it has always appeared peculiar to me that makers using this construction seem to believe that it is an object of beauty. To me it is not, and I believe that a side-splash apron should cover it.

It was surprising to see at the Salon and at the Palace Show how unsightly, from an artistic point of view, a perhaps clever mechanical construction can appear. In designing a chassis we must think of beauty as well as mechanics. A frame was shown without adequate means for covering the unsightly goose-necks at the front end, a cross-tube ran between them and was joined by an exceptionally large hideous casting containing numerous rivets. Mounting the springs on another car outside of the front goose-neck eye, with no attempt to cover this construction, ruined the entire front-end appearance of the car embodying it. Numerous cases were in evidence where a little better quality of sheet-metal work, or more of it, would give a finished appearance to the car.

In addition to the sod-pan apron extending entirely across the bottom of the car, we have side-splash aprons to imitate this effect; the majority of them are a disappointment in that they in no way convey the effect desired. Some are not made deep enough, as was evident on a number of cars, including a foreign car at the show; others have been dressed up with bevel edges which do not seem to fit into the design at this point.

The regular side-splash apron used with running-boards is sandwiched at its top between the body sill and the frame, and usually presents a horizontal surface which projects a short distance beyond the bottom edge of the body. Most of the side aprons without running-boards have followed this practice, and the flat or horizontal surface thus presented abruptly breaks up the otherwise smooth surface which can be obtained by making the side apron a continuation of the body side surface, curving it inwardly at the bottom.

I believe that a great deal more thought than has been given heretofore should be given to the body, fenders, aprons, etc., and their mounting, from the time the first line for the chassis is put upon the drawing-board.

SPRINGS AND SPRING SUSPENSIONS

BY E. FAVARY

THE chief factors affecting the riding quality of a motor vehicle are spring deflection, or amplitude; periodicity, or the number of vibrations per second; and the proportion of the sprung to the unsprung weight. Other factors are the wheelbase, the tread, the height of the center of gravity of the car and the effect of the front springs on the rear ones. The three main factors are considered at some length, various experiments being described and illustrated by diagrams. Spring inertia and the fundamentals of periodicity are then investigated, by experiments and mathematical analyses, in considerable detail. Experiments regarding possible future spring construction are described and discussed and the advantages offered by the suggested suspension are stated as sensitiveness at light loads; a minimum flexure for a maximum of axle motion; sensitiveness at all loads against quick upward thrusts of the axle; reduced weight of the unsprung mass; larger deflections at light loads and proportionately small deflections near the maximum load; and a saving in spring weight. [Printed in the January issue of THE JOURNAL]

THE DISCUSSION

Dr. BENJAMIN LIEBOWITZ:—The diagrams (Fig. 2) in Mr. Favary's paper showing the desirability of low unsprung weight are somewhat misleading, in that he has assumed the same spring for both large and small sprung weights. For a basis of comparison, however, the same static deflection should have been assumed. This fact makes the problem more complicated, but quantitative results were worked out and curves drawn (See Figs. 11, 12, 13, 14 and 18) in a paper I read before the Society in 1916 entitled On the Dynamics of Vehicle Suspension.[1]

The advantages of a low unsprung weight lie not only in the reduced vertical motions of the axle and body, but even more in the reduced fore-and-aft shocks and the increased ability of the car to hold the road.

Mr. Favary illustrates his theories with accelerations of 3888 ft. per sec. per sec. This is about 120 times the acceleration of gravity. Now, from the laws of motion we know that to impart to a body an acceleration of 120 times gravity, we must impress upon that body a force equal to 120 times its weight. The unsprung weight assumed in the paper is 300 lb. Hence, the wheel would have to have impressed on it a force of $120 \times 300 = 36{,}000$ lb. Since the wheel load for which the axle was designed is 1200 lb., a factor of safety of 30 would be required in the wheel, bearings, axle, etc. Obviously, such accelerations do not occur, except in serious accidents, and have no effect on spring design. In arriving at this acceleration, the author speaks of upward wheel velocities of 18 ft. per sec. To give some idea of what happens with upward velocities of only 12 ft. per sec., reference may be made to the curves of Fig. 14 of my above-cited paper.

The experiments described in Mr. Favary's paper cannot be applied to vehicle suspensions, because masses were attached to the spring whose weights were of the same order of magnitude as the spring itself; whereas, in all practical applications, the weight *on* the spring is fifteen to thirty times the weight *of* the spring. The periods, and there are many of them, of a spring itself are of little importance; it is the period of the assembly, spring and sprung mass, that counts. To illustrate by a very rough analogy, imagine an anchor-ring hung by a string so as to form a simple pendulum; the anchor-ring will have certain periods, which can be excited by striking it with a mallet; but these periods have nothing to do with the period of the pendulum, as a whole.

Spring inertia is a complicated subject. Those who may be interested are referred to vol. I of the Theory of Sound, by the late Lord Rayleigh. The complication lies in the fact that the velocity of propagation of transverse waves in a bar or plate is not a constant, as in the case of longitudinal vibrations, but increases with the frequency of the vibrations. I went into the theoretical side of this matter to some extent a few years ago and found that the inertia of the spring enters very little into the practical aspects of the problem. This conclusion has been experimentally corroborated several times; I may cite, for example, the steam hammer test which I made several years ago on a full-sized 2-ton truck spring, which was subjected to conditions far more drastic than would ever be encountered under the most severe service conditions. I do not know how high the accelerations due to the blows were, but they were certainly far higher than encountered in actual practice. If spring inertia would enter at all, it would certainly enter here, but there were no indications that it played any appreciable rôle. I shall revert to this test presently.

In the absence of more information on the experiments described, I cannot make any further remarks on this point, except to say that a bar can be made to vibrate transversely in a variety of modes; but this is no indication that the bar, when placed in a leaf spring, will vibrate in partial modes under actual service conditions.

The result of the experiments mentioned in Mr. Favary's paper, that to obtain a given period with a mass hung by a coil spring, twice the static deflection is necessary as compared with a leaf spring, is astonishing; and all the more so, since the author first derives the period formula,

$$\text{Period} = 2\pi\sqrt{\frac{m}{k}}$$

[1] See *S. A. E. Bulletin*, May, 1916, page 158.

which is readily transformed into

$$\text{Period} = 2\pi\sqrt{\frac{\delta}{g}}$$

where δ, the static deflection, enters as the only variable. Here again the author probably used weights which were smaller than the weight of the coil spring itself.

If there is any doubt as to the accuracy of the period formula, as applied to a coil spring whose mass is small compared with that of the suspended weight, which condition always obtains in practice, it can be checked on the seismograph which I have here. It is true that a coil spring can be more easily set into partial modes of vibration than a leaf spring; but if this made much practical difference, we should feel on the finest Pullman cars a constant disagreeable tremor, due to the impact forces of steel wheels on steel rails; which forces are much higher than those encountered in motor vehicles.

There is one other point in this connection. Assuming that a given coil spring, by itself, has higher natural

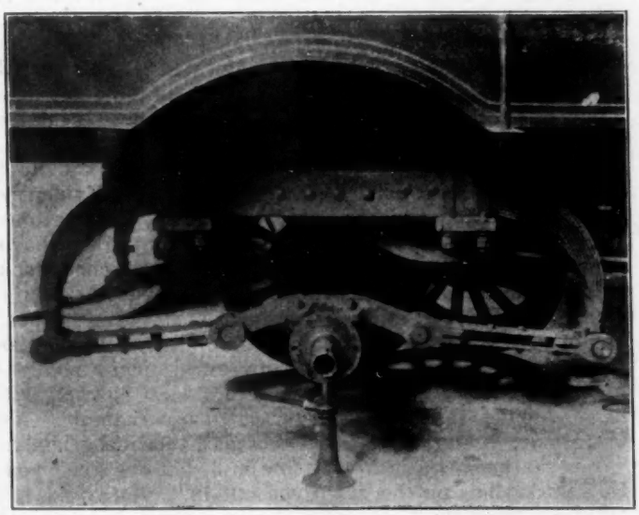


FIG. 1

frequencies of vibration than a corresponding leaf spring, by itself, this would indicate relatively higher rates of wave propagation in the coil spring. Higher velocities of propagation, on the other hand, would make a spring more suitable for rapid vibrations. If any conclusion from the experiments described were at all possible, it would be that the coil spring is better for rapid vibration than the leaf spring.

In Fig. 10 the author illustrates a lever suspension which he indicates would solve the alleged problem of spring inertia, except that the lever would break on account of the inertia forces under high accelerations. This point is worthy of further scrutiny. To carry 900 lb., such a lever, if say 24 in. long, and properly designed, would hardly weigh 32 lb. Also, its radius of gyration would certainly not exceed about 12 in. Now, let

ρ = Radius of gyration or 1 ft.
M = Mass of lever $\frac{\text{Weight}}{32} = \frac{32}{32} = 1$
α = Angular acceleration
a = Linear acceleration at end of long arm
l = Length of long arm or 2 ft.
F = Inertia force at end of long arm

According to well-known formulas,

$$M\rho^2\alpha = Fl$$

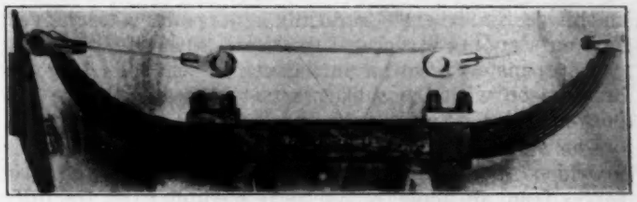


FIG. 2

But the angular acceleration α is related to the linear acceleration a by

$$\alpha = \frac{a}{l}, \text{ hence}$$

$$M\rho^2\frac{a}{l} = Fl, \text{ or}$$

$$F = Ma\frac{\rho^2}{l^2}$$

Putting in the values of $M\rho$ and l indicated above, and choosing for a the acceleration used in the paper, of 3888 ft. per sec. per sec., we get

$$F = \frac{32}{32} \times 3888 \times \left(\frac{1}{2}\right)^2 = 972 \text{ lb.}$$

In other words, even with the acceleration assumed in the paper, which would destroy the wheel and axle, the inertia force on the lever would be about the same as the normal load on the lever, and would be taken care of by ordinary factors of safety. In fact, lever suspensions have been built and tried out. They have not made progress primarily because they do not achieve any new result.

After the lever suspension, the author discusses what may be called suspensions proper. The use of such suspensions dates back to the stage-coach days. In fact I have seen one illustration which is taken from a British patent dated 1798. I believe there are extant in this country several examples of coaches having that type of spring support. The contention that such suspensions offer a saving in weight of spring material is contrary to basic principles, that the weight of a spring is determined by the amount of energy it must store, the fiber stress, the type of spring, whether torsional or flexural, and the uniformity of stress distribution, which determines the weight efficiency. Furthermore, the use of straight springs, such as shown in the author's Fig. 14, leads to an utterly impracticable design. When I laid down the design shown in the accompanying photograph, I calculated out some straight springs. But the depth of the springs came out about the same as their length, and the leaves were too thin for a practical design.

In discussing the use of curved springs in such suspensions, the author chose a rather poor example. About four or five years ago I equipped a 2-ton truck with springs built along such lines, a photographic view of which is shown in Fig. 1. There is a radical departure

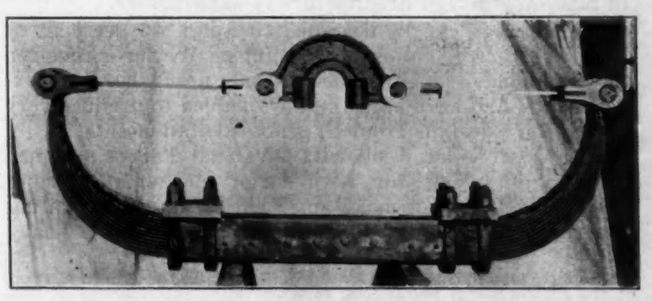


FIG. 3

in this design, whereby radically new results are achieved. The outstanding structural feature is that the springs of the suspension have an initial strain which is large in comparison with the subsequent strains due to axle and body motions. See Figs. 2 and 3.

The important results achieved are (*a*) a means is provided for obtaining substantially perfectly elastic forces from an imperfectly elastic medium; (*b*) the fiber stress in the spring material, though high, is nearly constant, and breakage due to fatigue is thereby eliminated. This latter is proved not only by Wöhlers' famous experiments, made over fifty years ago and subsequently verified by many experimenters, but also by our own comparative steam hammer test. In this test we delivered to the ordinary spring blows which caused a deflection of full-load plus 60 per cent. At 15,000 blows the spring began to fail; at 30,000 it was a misshapen mass of steel.

To the "constant-stress" suspension we delivered blows causing a deflection of full-load plus 140 per cent. At 40,000 blows a tension member broke at a rivet hole. The tension member was repaired and the spring put back on the truck. That truck is in operation today with the same set of springs. If any appreciable buckling stresses existed in this suspension, the steam hammer would certainly have found them.

I spoke of steel as an imperfectly elastic medium. Is it? As a result of five years of observation and experiment, during the last six months of which we have had means at our disposal, through the development of the seismograph, which have hitherto been unavailable, we have found that the conventional leaf spring, when properly designed, is a very satisfactory device, when new. The basic defect of the conventional spring is that it does not stay that way. And the trouble is not due to the growth of interleaf friction, so much, but to the growth of molecular friction. In short, we have found that the chief and most prevalent cause of hard riding is spring fatigue.[2]

In the "constant-stress" suspension, not only is fatigue itself minimized by the fact that the stress range is small, but also, even if the spring material should develop internal friction or hysteresis, the suspension will continue to ride with approximately perfect elasticity. This will be proved both theoretically and practically in a future communication.

In the suspension shown in the figures, we ran the maximum stresses higher than would be permissible in ordinary springs. Also, because the springs were designed for practically one position, we obtained very high weight efficiencies in the spring material. In consequence, the weight of spring material required was but little more than in the conventional type of spring. Nevertheless, the suspensions, as a whole, did weigh considerably more than the equipment they replaced. Furthermore, it was not always easy to find space for the spring material, and to make the design architecturally satisfactory.

Coil springs can be designed to weigh 40 per cent or less than corresponding leaf springs. We have reverted to coil springs, which we used in our first laboratory experiments, and have been thereby enabled to produce very satisfactory designs from all practical standpoints.

E. FAVARY:—Dr. Liebowitz says that I have assumed "the same spring for both large and small sprung weights." I did not make any such assumption. In my paper, Fig. 2, I show two examples, a light and a heavy sprung weight; the mass of the latter appearing to be more than 20 times that of the light weight. Would any engineer consider for a moment the use of the same spring for two weights of such disparity? I stated plainly, when describing the case of the heavy unsprung weight that "no matter how weak or strong the spring above which supports the light weight may be, it will carry the small weight along with it."

In the paper referred to, which Dr. Liebowitz read in 1916, he says that "to make the subject amenable to analysis and the results simple enough" he introduced "approximations and limitations." It is principally in this respect that our papers differ. He is thinking of the results of the mathematical analysis and uses approximations to ascertain desired results, while I analyze the problem as it appears to me in practice, and apply mathematics to it.

Dr. Liebowitz says that I have illustrated my theories with accelerations of 3888 ft. per sec. per sec. I assumed that, if a wheel, when hitting an obstruction at a speed of 49 m.p.h., rises 1 in. when traveling 4 in. forward, it will have a vertical acceleration of 3888 ft. per sec. per sec., not an impossible condition, Dr. Liebowitz's opinion to the contrary notwithstanding. I stated why I selected this rather unusual case, and how, by permitting the axle to move slightly backward, which happens in practice more or less, the upward acceleration can be reduced. Why did Dr. Liebowitz not try to disprove my figures from the assumed 1-in. rise of the wheel? Evidently because he cannot do so. He says such accelerations have no effect on spring design. I think they have very much to do with it, as showing what conditions we would actually get oftener if the wheel velocity were not slightly retarded as mentioned in my paper. He quotes from the laws of motion, that a force 120 times that of gravity has to be impressed upon a body to give it the acceleration I mentioned. This is true, but he misapplies this well-known fact to my example. As Mr. Huxley remarked to one of his mathematical friends: "Your mathematics is a very fine mill, but the grist you get out depends on the grain you put in."

In my example I assumed the unsprung weight per wheel to be 300 lb. This includes the wheel complete, the spring, one-half the weight of the entire rear axle and axle housing containing the differential, and a part at least of the propeller-shaft. To begin with, the center of the axle and axle housing in the center line of the car will have an acceleration only one-half that of the wheel, when the latter hits an obstruction. Furthermore, the major portion of the spring will have a lower acceleration than the wheel, since it flexes, and that part of the spring attached to the frame and immediately adjacent will have a very low acceleration indeed. The actual weight affected by the maximum acceleration is therefore in practice very likely not more than 30 per cent of the unsprung weight, when a wheel surmounts an obstruction. To find the actual stress in the wheel, there must be added that required for the mass exposed to the lower acceleration. We are therefore nearer correct in arriving at the stresses in the wheel when adding another 30 per cent to the weight, and taking the acceleration of the mass at 3888 ft. per sec. per sec. We thus have 120 x 180, or 21,600 lb.

A knowledge of the strength of wood wheels might be of interest in this connection. The University of Michigan has made tests of automobile and truck wheels[3], but only three examples were given, the first of which evidently comes nearest to our example of carrying a load of about 1200 lb. Under direct load the wheels supported

[2]See article on Elasticity, by Lord Kelvin, in the Ninth Edition of the Encyclopedia Britannica, for interesting information on this matter.

[3]See Hayes, *S. A. E. Transactions*, Part II, 1914.

40,800, 114,000 and 140,000 lb. respectively. In these tests the remarkable recovery of wood wheels to their original shape when loaded to almost their breaking point was noted. Hence, I believe I am right in maintaining that the wheel mentioned in my paper would not break if occasionally subjected to a force of 21,600 lb. or even considerably more. Dr. Liebowitz not only speaks of the wheel but states that the bearings and the axle would have to withstand a load of 36,000 lb. and have a factor of safety of 30. Let us take the bearing. I surmise he refers to the wheel bearing. Here the only weight subjected to the maximum acceleration is the portion of the axle in the wheel bearing proper. The weight of the wheel and the spring does not enter here, but only that of the axle and axle housing which, as mentioned before, has at the center of gravity an acceleration of only one-half the maximum. Taking this into account, it will be admitted that the ordinary factors of safety of the bearing and the axle are sufficient, even if the wheel should on exceptional occasions have an acceleration of 3888 ft. per sec. per sec.

These periodicity experiments (See Fig. 4) were described in the paper to show how the load affects the periodicity. The weight attached to the spring, as far as the coil spring is concerned, was not of the same order of magnitude as the coil spring itself as stated by Dr. Liebowitz. I will discuss this in a later paragraph.

Dr. Liebowitz says that he went into the theoretical side of spring inertia and found that it enters very little into the problem. In corroboration of his conclusion he cites steam-hammer tests and, while admitting he did not know what the accelerations of these were, asserts "they were certainly far higher than those encountered in actual practice." He concludes the paragraph with "there were no indications that it (spring inertia) played any appreciable rôle." Such statements seem to me to be misleading. He did not look for spring inertia. He speaks of no means or devices for ascertaining it. Let us analyze the steam hammer he mentions and find its acceleration when used to flex a spring from no load to its maximum deflection. From his Fig. 3 I assume the maximum deflection until bottom is hit to be 9 in. Judging from his figures, I take it the steam-hammer ram with piston weighs certainly not more than 350 lb. and has a stroke of 2 ft. To be on the safe side, let us assume the steam pressure behind the hammer to be 7000 lb. In such case the acceleration as the ram descends would equal

$$g + \left(g\ \frac{7000}{350}\right) = 21\ g$$

or twenty-one times gravity, i. e., 675 ft. per sec. per sec.

Since the stroke h is 2 ft., we have, by the well-known laws of motion, the formula

$$h = \frac{v^2}{2\,a}$$

v being the velocity, and a the acceleration. Hence

$$v = \sqrt{2\,a\,h} = \sqrt{2 \times 675 \times 2} = 52 \text{ ft. per sec.}$$

The maximum "give" s, from no load to maximum deflection, we have assumed to be 9 in. or 0.75 ft.; that is to say, the hammer is stopped in 0.75 ft. Hence

$$a = \frac{v^2}{2s} = \frac{2700}{1.5} = 1800 \text{ ft. per sec. per sec.}$$

This is therefore less than one-half of what it occasionally is in practice, as described in my paper. Because a steam hammer has a very high acceleration when used for forging where its motion is stopped in, let us say, ½ in., Dr. Liebowitz evidently concluded that the acceleration must be very high when stopped by the flexure of a spring. If the hammer were stopped in ½ in. its acceleration would be about 32,000 ft. per sec. per sec. Therefore, on the face of it, his steam-hammer test is useless as far as high acceleration or spring inertia is concerned. Assuming, however, for the sake of argument, that he could obtain an acceleration as high as the figure I gave, how would this be indicated in his experiment, and how could he measure what effect it had upon passenger comfort in a car? In my paper, Fig. 5, I showed what took place in a thin spring when suddenly started vibrating. I think that this takes place in a very much smaller degree in ordinary leaf springs under very high accelerations, and I therefore said that it "would indicate that if we set the spring vibrating at a slower rate it would be more satisfactory." I finally described some constructions wherein the spring would flex at a lower acceleration even though the axle acceleration were high. Dr. Liebowitz offers no constructive criticism, but mentions the steam-hammer test of whose acceleration he admits he knows nothing, nor does he in the least indicate that he, or any other man, has ever hunted for spring inertia. He says nothing except that this is a complicated subject, that he went into the theoretical side of it a few years ago; but of proofs to sustain his allegations contraverting my statements, he offers none.

Dr. Liebowitz ascribes to me statements which I never thought of making concerning periods of coil and leaf springs. I described certain experiments and, with the *coil spring tested*, it was found that twice the static deflection was necessary to obtain the same periodicity as that of the leaf spring tested. I have plainly shown that the periodicity of any vibrating body is

$$T = 2\pi \sqrt{\frac{\text{Resistance}}{\text{Restoring Force,}}}$$

and I think I explained the matter with sufficient clarity for any one to see that the mass and the restoring force alone govern the periodicity, and I so stated in my paper. Hence, if the coil-spring weight were the same as the leaf-spring weight which affects the periodicity, not the entire leaf-spring weight, and if its restoring force were the same, i.e., if the deflection per unit load were the same, which means that the coil diameter would be unusually large, their periodicity would be the same. I wanted to bring out forcefully the lower periodicity of coil springs as used today with spring suspensions; that is to say, in coil-spring shock-absorbers, which have a smaller deflection and a considerably smaller periodicity. Dr. Liebowitz is wrong in stating that I "used weights which were smaller than the weight of the coil spring itself." The weight of the coil spring used in these experiments was 2¾ grams and that of the load 70 grams, or more than 25 times that of the spring. The coil-spring diameter was 7½ mm., and the size of the wire 0.533 mm.; the static deflection 5 in.; and the periodicity 80 vibrations per min. He says in this connection, "If there is any doubt as to the accuracy of the period formula . . . . . it can be checked on the seismograph which I have here." If Dr. Liebowitz's seismograph does not show substantially the same periodicity as that I have specified for the spring described, the seismograph is unquestionably inaccurate.

As to Dr. Liebowitz's remarks on coil springs fitted to Pullman cars, the maximum inequality of the rail surface is minute compared with that of the ordinary road surface, and the analogy does not hold good for road vehicles. In a Pullman car the total load is enormous compared with that of a coil spring, and there are a large number

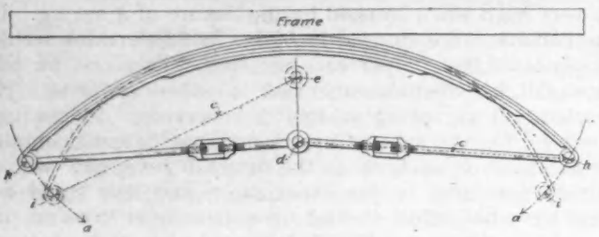


FIG. 4

of short coils, short in deflection/load ratio. The longer a coil spring is, the more its tendency is to partial modes of vibration, and the greater they are.

A lever suspension has a number of defects, I only mentioned one great disadvantage. As to Dr. Liebowitz's mathematical proofs, let him take a sledge hammer and hit the lever, or let him place this under the steam hammer, and he will find it will snap or bend at once. He may throw a wooden bar in the air and hit it while in the air; it will break if hit hard enough. Not even the theory of the ballistic pendulum holds good here; if it did we could so place the axis of the suspension that the axis of rotation might also be the axis of percussion, in which case it would break at some other point than the axis, but it would break. He is forgetting that there is another end to the lever, the end which deflects the spring. Let us take his figures and say that the long arm of the lever, Fig. 10 of my paper, is 2 ft. long, and the small arm 1 ft. Let us assume that the static deflection of the end of the lever attached to the axle is 4½ in. under 900 lb. of unsprung weight, as was stated. The axle will thus rise, or the body descend, 1 in. for each 200 lb. of load. Let us say that the maximum additional motion of the axle is another 4½ in., requiring the appli-

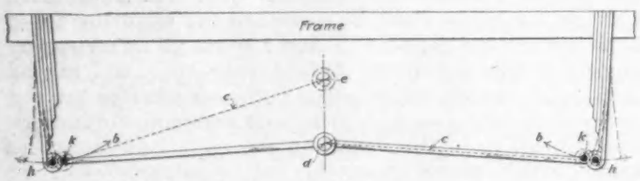


FIG. 5

cation of another 900 lb. when moved slowly. Thus, while it would take another 900 lb., or a total of 1800 lb., to move the axle up slowly, Dr. Liebowitz tells us, under a most severe shock, the stress in the lever would be only 972 lb. or, to use his words, "even with the 3888 ft. per sec. per sec. acceleration assumed in the paper, which would destroy the wheel and the axle, the inertia force on the lever would be about the same as the normal load on the lever," etc. He concludes this subject with the statement that lever suspensions have been tried but "have not made progress primarily because they do not achieve any new result." Does he know where lever suspensions have been tried and what their results have been? He speaks of none. He attempts to prove what the actual stress in the lever is without giving an account of a practical test. I constructed one experimental lever suspension in 1913 and, when testing it for rapid blows, found that it snapped. Hence, I spoke of this as the great disadvantage of lever suspensions.

With regard to suspension proper and in reference to the 1798 British patent, Dr. Liebowitz says, "I believe there are extant in this country several examples of coaches having that type of spring support." The British patent shows a coil spring in a roller around which one end of a strap is wound; as the load increases, this coil spring permits the strap to elongate. This has no bearing on present-day vehicle suspension. I should like to ask whether he refers to the latter type or to the type described in Figs. 13 to 15 of my original paper. The construction I have shown he then proceeds to discuss in the following words: "The contention that such suspensions offer a saving in weight of spring material is contrary to basic principles," etc., and his remark about the design of straight springs that "the depth of the springs came out about the same as their length, and that the leaves were too thin for a practical design," is remarkable. When describing this spring he first described his leaf spring in certain official documents in Washington, where he and I had an interference. Thereafter he abandoned leaf springs and returned to coil

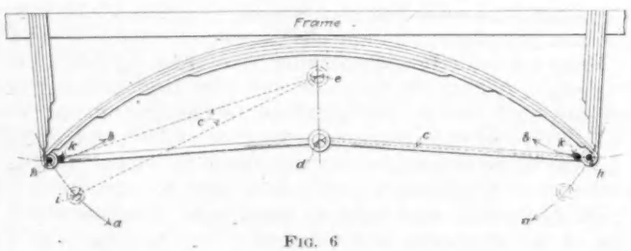


FIG. 6

springs. With reference to his Figs. 1 and 3, he says that he divides the spring because it saves unnecessary length of spring material. In other words, he divides the spring to save spring weight. If he thus saves weight, by so much more do I do the same with my short straight spring, the tension on the spring eyes being the same. The construction shown in his figures is lighter than it would be if made with a semi-elliptic spring. By glancing at his Fig. 3, it is self-evident that if the middle portion were spring material, it would be heavier than when the spring is divided as shown. But in addition, if the spring flexed at or near the center, the number of leaves would have to be increased, since the distance from spring seat to spring eye would be greater, and the bending moment at the seat would likewise be greater. He was therefore right originally in stating that there is a saving in spring weight by dividing the spring instead of making it one continuous spring seated at the center. By going a step further, dividing it still more, and making the springs straight (see Fig. 5), the same ratio of saving continues and, in addition, it can be made lighter because the length between spring seat and spring eye is decreased

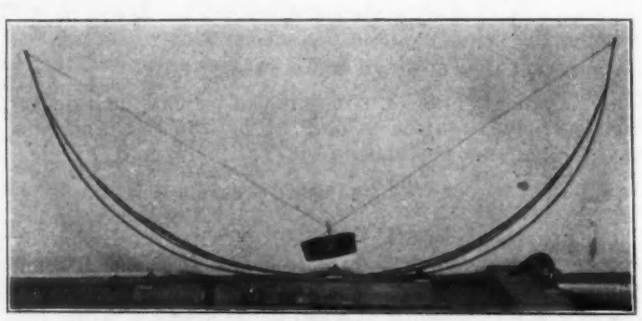


FIG. 7

still further, thus further reducing the bending moment at the seat. There is still another point worthy of notice, namely, that the flexure in the spring per unit length is considerably less, which means that a much shorter spring can be used when it is made straight. In the illustrations, Fig. 4 shows a semi-elliptic spring embodied in this type of suspension. Fig. 5 shows short straight springs, and in Fig. 6 both types are shown in one view to bring out more clearly their distinguishing features. In Fig. 6 is illustrated what happens when a semi-elliptic spring is used instead of two short straight springs. While the axle rises from *d* to *e*, the spring eye of the semi-elliptic follows approximately the path *a* and assumes position *i*. In the case of the straight spring the eye would follow approximately arc *b* and move only the short distance from *h* to *k*. Therefore the outstanding features of a straight spring over a semi-elliptic spring as well as over the constructions Dr. Liebowitz shows in his discussion are (*a*) that the spring can be made considerably lighter and shorter; (*b*) there is less flexure per unit length and, (*c*) the bending moment at the seat is less. This latter varies directly as the length, if the tension and the direction of the flexure are the same. Hence, it is erroneous to say that a straight short spring does not save spring weight, and that the leaves would be too thin, etc.

Referring to the claim of the initial strain, I originally showed the spring under considerable initial tension; in fact, the construction could not work without it. In my construction, Fig. 5, the position of the spring before being connected to the tension rods is shown dotted. Dr. Liebowitz also disputes the existence of buckling stresses to which I adverted in connection with the semi-elliptic spring when applied to this type of construction. The accompanying Fig. 7 clearly illustrates the buckling stress, and this also holds good to some degree in the structures disclosed in his figures, although much less than in the semi-elliptic.

When the springs are straight, or when they are arranged with their seats still further apart than their eyes, so as to have the direction of the force exerted on the leaves at right angle to their length, a most important matter, which is impossible of attainment with the structures he illustrates, the spring can be made considerably lighter than those he shows; the flexure per unit length is less; the bending moment at the seat is less; the spring is more sensitive, since the spring eye moves a smaller distance for a given axle displacement; and there are no buckling stresses. Another disadvantage of the construction shown by him is that the leaves are made to flex in the reverse direction from that customary with leaf springs.

Regarding Dr. Liebowitz's plea for coil springs, I fear that it will be somewhat difficult to prove the coil type of springs superior to leaf springs for use in vehicle suspensions.

THE MEASUREMENT OF VEHICLE VIBRATIONS

BY DR. BENJAMIN LIEBOWITZ

THE five fundamental criteria of the performance of a motor vehicle as a whole are stated and that of riding comfort is then investigated at length with a view to determining methods of measurement of the two classes of vehicle vibrations that affect the riding qualities of a car, so that suitable springs can be designed to overcome them. The underlying principles of the seismograph are utilized in designing a specialized form of this instrument for measuring vehicle vibrations, the general design considerations are stated and a detailed description is given. This is followed by an explanation of the methods used in analyzing the curves obtained, thus making possible a standardized measurement of riding comfort. The factors determining riding comfort are then analyzed in connection with spring-development work, the most important are summarized and the preliminary experimental results of those directly determined by the seismograph are outlined. The forced and the free oscillations of a vehicle body are mathematically analyzed in Appendix I. Two theorems are developed in Appendix II; one for stiffness and the other for static deflection of lever-suspension springs. [Printed in the January issue of THE JOURNAL]

THE DISCUSSION

H. M. BROWN:—We are all aiming toward the same thing, of course, and we all get different results. I devised an instrument to do in a much cruder way what Dr. Liebowitz has described. I obtained the little wiggles he mentioned, finding that it did not require a new car to get them. We could get very decided wiggles with an old car. If the springs are lubricated, wiggles almost disappear. When the springs are old, if a reasonable amount of the excessive friction between the leaves is eliminated, a smooth riding car results.

R. W. A. BREWER:—Reference was made to a proposed method of producing a diagram on a fence from the side of the car. Before leaving England, I saw some very interesting photographs that were taken by night on Brooklands track. The car had on to its side several lamps attached in various vertical positions, and a series of lamps on two wheels. Photographs were then made as the car went over an obstacle on the track. These various photographs gave, of course, exact permanent records of the vertical heights of the various parts of the machine, under different conditions. This is a very simple method of obtaining results when one is investigating spring problems.

B. F. TILLSON:—I would like to raise a question in regard to the differentiation between wheelbase and springbase. Is the contention in regard to a long springbase of merit? Casually, it might seem correct to assume that the point of attachment of the spring to the car definitely affects the displacement, or the amplitude of motion of the car in a vertical plane. If that is responsible for the discomfort of the passenger, it would then seem that an elliptic or a semi-elliptic spring, where there are two points of attachment for one spring and whose effective point of attachment to the chassis would seem to be the mean distance between those two points of attachment, would be at an extreme disadvantage, as compared with the cantilever type of spring, whose single point of attachment might be at the remotest distance, or at the extremity of the car, away from the axle. If, however, the acceleration is the chief function of dis-

comfort, it might seem that that point is poorly taken, and that the difference between the length of wheelbase and springbase would not be of great moment.

A MEMBER:—I think that if the springs are made long enough, wide enough and thin enough, all the present wiggles, jounces and troubles will be avoided. The principal trouble in automobile springs is through a limitation of construction designs. Springs are made deep and short. All the levers and auxiliary springs used are to dodge this question of having the springs long, wide and thin. Reference was made to the old-style coach. I have had some experiences in the carriage trade and call the attention of automotive engineers to carriage springs. The springs of the easier-riding carriages, like the coaches, or of the heavier ones, were much longer, being several times longer in proportion to the load carried, than anything we have in the automobile today. The other point is that the spring should not do anything more than act as a spring. To make a torsion or a thrust-rod out of a spring, introduces some wiggles and produces stress of materials and spring fatigue.

O. A. MALYCHEVITCH:—Some years ago I was connected with a factory in England which is engaged in building all the omnibuses for the London General Omnibus Co. An investigation was made of the question just discussed on the basis of a series of articles printed in one of the best automobile publications in France.[4] The result showed that the front axle and frame have their own vibration, i.e., their own average amplitude and length of wave or period of vibration. The method applied was similar to the one just mentioned. Lights were fixed on the front and back axles, frame and body of an omnibus, which passed before the camera at different speeds on different kinds of road with and without obstacles. The result corresponded to that described in the articles mentioned and also showed that with an omnibus having solid tires, when traveling over an obstacle, the amplitude of vibration and vertical speed of the frame and body grow enormously with increase of speed, while the front axle varies but little. The period of vibration or length of wave of the frame and axle increases if the load and speed increase, and by varying the position of the load or passengers different combinations and coincidences of the wave of vibration can be obtained. With pneumatic tires the result will be altogether different. Therefore, any problem concerning the measurement of vehicle vibration should be considered very carefully, on account of these differences in vibration of each principal part of the chassis or each principal wave which may occur in a solid-tired omnibus having a constantly varied load.

R. A. SCHAAF:—W. C. Keys brought the method of measuring the performance of springs by means of lights to our attention at a meeting of the Pennsylvania Section of the Society about two years ago. In the experiments he described there was one light on the axle, one on the passenger's hat and another on the body of the car. The relative motion of all three was shown very effectively. As a previous speaker said, it is not a question of the vibration of the passenger, car or axle, but of the relative motion of all three with respect to each other.

Another speaker said that case of riding is altogether a matter of spring length. In the old horse-drawn vehicle days the length of a spring compared with the load it carried was very much greater than in the modern automobile. I agree that if the spring is long enough and its leaves thin enough all the little wiggles we have heard so much about will disappear.

As spring-makers we are not in the habit of talking about periodicity or amplitude or any of the other related terms. Instead we always speak of the deflection or travel of a spring. I do not know exactly what relation exists between travel and amplitude and periodicity, but I do know that the travel of a spring affords a very simple method of comparing the riding quality of one spring with that of another. For instance, if one spring has a travel of 4 in. and another a travel of 5 in., other things being the same, the spring with the 5-in. travel will ride better than that with 4 in. By "travel" is meant the difference between the height of the spring as it lies on the floor and its height under the loaded car. It is the distance it "travels" or deflects when its full load is applied.

G. R. PENNINGTON:—I may be mistaken in this but I understand that to get a long period it is the main object of a designer to soften out the bumps if the period is long. This period varies inversely as the square root of the pounds per inch deflection. Therefore, the pounds per inch should be small if the period is to be long and if the car is to ride smoothly. If the number of pounds per inch is small, we should have a great deflection in a given bump. We are limited in that, in passenger-car designs, by the construction of the frame and by the amount of movement that we permit the passenger to have. That is the real limitation as I see it. The whole thing starts from the total amount of movement the body can be permitted to have. Given this, we want the softest spring; having obtained such a spring, we can hardly go any further in other variations because all conditions have then been established.

A MEMBER:—In the past year I have had the questionable pleasure of driving five of the cheaper grades of car. They all had different styles of spring suspension. Aside from the mathematics of the proposition, what contributed more to ease of riding in my experience was the direction in which the spring allowed the axles to deflect when a bump was struck; in other words, I was interested as to the length of time it took the axle to move relative to the body, and in what direction it moved. That has not been mentioned. It is my experience that the full elliptic springs give better results than any of the other methods of springing.

F. C. MOCK:—As one of the previous speakers said, a good basis for analysis of spring action is the deflection of the spring when its normal load is placed upon it. Suppose we have two springs, one of which deflects 5 in. when its normal load is placed upon it, which is about the deflection used on the rear springs of the higher-grade cars, and another which goes down but 2½ in. this being typical of a very stiff spring suspension. Assume that the cars carrying these springs in turn strike a bump 3 in. high, at such a speed that the first-mentioned spring deflects 2 in. This leaves 1 in. of the bump, less the tire and seat-cushion action, which the passengers will receive. If the second spring, half as flexible, takes the same bump at the same speed, the spring will deflect about half as much, or 1 in., leaving 2 in. of bump for the tires, seat cushions and passengers to absorb. Thus, absorption of road shocks increases with a high initial deflection of the spring and requires room for considerable travel between the wheel and axle system and the body. The early coaches just mentioned always had 8 in. or more of clearance between running gear and body.

Often important to the purchasing agent, there is a

[4] *La Technique Automobile et Aerienne*, 1914. Les Pertes par Roulement des Automobiles.

physical law that for a given load and given fiber stress the weight of material in springs must be proportional to their deflection. As we buy our springs on a price per pound basis, the 5-in.-deflection spring just mentioned would cost at least twice as much as the 2½-in. This is why the springs of higher deflection are found on the high-priced cars.

Another point of comparison, not always to the advantage of the large-deflection spring, is the force and distance of reaction. A spring tends, in general, to give back in throw just as much energy as is represented in its deflection. In the preceding illustration, after the 5-in.-deflection spring has reached the top of the bump, it will tend to throw back 2 in. to reach a condition of normal stress, and may continue 1¾ in. beyond that; a total throw of 3¾ in. The 2½-in.-deflection spring will have about 1¾-in. throw, but this will take place in less time, so that acceleration for some of the passengers may be of equal or greater violence. In practice this rebound action seems to constitute the limit on the flexibility of springs that we can use on automobiles. It seems that there is a certain amount of throw that can be tolerated, possibly depending upon the ratio of sprung to unsprung weight. Inasmuch as the stiffness of the spring for a given deflection on a given bump must increase as the square of the speed, to hold the deflection and resulting throw within reasonable limits on racing cars, requires very stiff springs.

In dropping into holes, the more flexible spring has the advantage. Let us assume that the car of our previous illustration reaches a depression in the road 2½ in. deep. If the wheel of the 2½-in.-deflection spring should reach the bottom of the hole before the body falls very far, the spring will be practically free, that is, exerting no support upon the body and the body will fall with the acceleration of gravity into the hole. If we assume that with the 5-in.-deflection spring the wheel reaches the bottom of the hole before the body has fallen perceptibly, the spring will still be under 2½-in. compression, will be exerting one-half of its normal sustentation against the body, and the body will tend to fall into the hole only half as fast. In other words, when you see a car pass over a choppy road with the body steady but the wheels jumping up and down rapidly, the springs of that car are relatively flexible. With stiff springs the car will ride much more roughly.

As to the matter of balance, most studies in spring action are confined to the action of the front or rear springs individually, whereas their relative action has a prominent effect as regards ease of riding. When you impart a shock to one end of a body whose mass is distributed throughout its length, as in Fig. 8, it takes up a motion of translation and of rotation, with the result that the other end actually moves toward the shock. In an automobile, as you will find upon observation, when the front end rises on a bump the rear end goes down, and the amount of this drop often determines the force of the subsequent shock of this same bump on the rear passengers. This action is a function of the weight distribution, as will be evident from the middle and bottom portions of the accompanying drawing. Note the travel of the points *a* and *b*, at which the passengers are usually located. The arrangement in the middle gives the easiest riding at the point *a*, and would be a weight distribution suitable for a roadster. That at the bottom would give much better riding qualities in the rear seat and almost as good in the front seat, but will be more apt to skid rounding corners, of course. The difference in riding with these different weight distributions is easily demonstrated by towing a chassis with a weighted load which can be shifted to different points.

Another point in the interrelation of the front and rear springs is their periodicity. If you try to "teeter" the front or rear end of an automobile, which can be done if there are no shock absorbers, it will be found that each pair of springs tends to oscillate at a definite rate which will correspond pretty closely with the formula already mentioned,

$$\text{Time of one oscillation} = 2\pi\sqrt{\frac{\text{initial deflection}}{32.2}}$$

Purely as a matter of interest, I have made it a point to observe the periodicity of different cars I have encountered with exceptional riding qualities, either good or bad. What we know as a stiff spring will have a

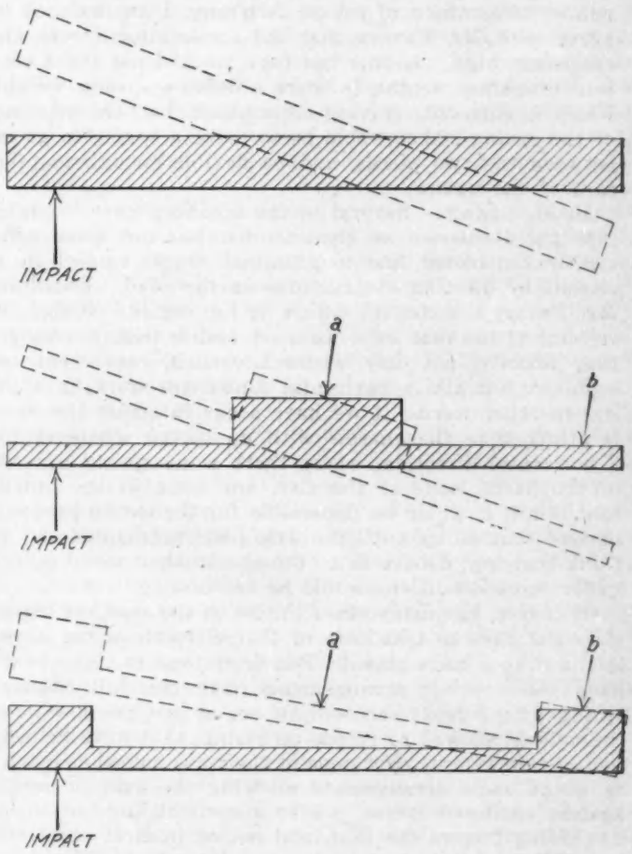


FIG. 8

frequency of 140 to 180 vibrations per min. What is generally known as a long slow spring will have a frequency of about 90 vibrations per min. It is noticeable that when the periodicity of the front and of the rear springs is approximately equal, the car has a very strong tendency to pitch and to take up a rocking motion when going along the road. The best riding cars seem to have a frequency of between 85 and 100 vibrations per min. on the rear springs and all the way from 120 to 160 vibrations per min. on the front springs. Provided the unsprung weight is not too high, the spring action is retained within bounds by bumpers and recoil checks and the load distribution is reasonably good, I believe that 120 to 130 vibrations per min. of the front spring, this is a fairly soft front spring and it is necessary that the

steering length be laid out so that the motion of the front springs does not steer the car from side to side and 85 to 90 vibrations per min. under full load for the rear spring, will give the best riding qualities over an average of all conditions of use.

F. JEHLE:—I am wondering whether the relation between sprung and unsprung weight has been given all the consideration it deserves in this spring problem. It seems to me that the wheel can be considered as a cam follower. The flat surface of the road is the base circle of the cam action, and the bump in it is the cam. With a given weight to accelerate, which is the unsprung weight, we must put on top of that a certain weight to hold it down, to make it follow the road. That force will be represented, I believe, by the sprung weight of the car. I do not wish to return to the acceleration problem but, neglecting the portion of the energy absorbed by the rubber tire, which of course is wrong, I am inclined to agree with Mr. Favary that the acceleration forces are extremely high. If this has been worked out for a certain unsprung weight, is there a definite sprung weight which is correct? Having determined that, the problem of the spring-maker would be to make a spring to go in between the two pieces, and be flexible enough to take care of the bumps.

H. M. CRANE:—Several of the speakers have brought into the discussion an element that has not been sufficiently considered, the longitudinal shocks caused in a chassis by meeting obstructions on the road. Recalling Mr. Favary's sketch in which he figured the change in velocity of the rear axle, we must realize that, to change that velocity, not only would a vertical component be required, but also a horizontal component working with it. In other words, if we have a car in which the axle is attached to the chassis with no spring whatever in a horizontal direction, where there is no spring in any of the parts, none at the tire, and none in the bump that is hit, it would be impossible for the car to proceed beyond that bump until the axle had surmounted it. I think that any figures as to the shocks that would occur under those conditions would be astounding.

Of course, like many other things on the road, we leave it to the tires to take care of that element, or we have left it so to a large extent. But from time to time there have been spring arrangements, like the full elliptic spring or the front semi-elliptic set at a slope in which the axle is allowed to recede on rising, that have helped to a certain extent. But none of them has helped as much as would some arrangement allowing the axle to move against spring pressure, not in a vertical line but in a line rising toward the rear, and not as in most cases on an arc of a circle swinging around a pivot. The full elliptic spring, due to its height and the possibility of bending under, has in a way provided this condition. There is still a third point, the lateral vibrations which have been too little considered and which again a full elliptic spring has helped a great deal. The car proceeding down the road encounters unequal obstructions on the two sides; the axle is forced to take positions angular to the body center, instead of parallel with it. In practically all spring suspension, the attempt to take those positions results in side-thrusts in the chassis frame, which may become very severe. The full elliptic spring, as can readily be seen, being 8 to 10 in. high from the point of support on the axle to the point of support on the frame, and being relatively weak sideways due to the narrow leaves, gives an excellent cushion for this type of shock. The prevailing type of flat semi-elliptic spring with wide leaves is about the worst kind of construction that we can use in this regard. Unless something is done in the method of attaching the spring to the chassis frame, we will develop an entirely new kind of vibration that is far from comfortable. If Mr. Liebowitz can add some elements to his apparatus to take in these other vibrations, he will have made further progress.

E. FAVARY:—To answer the remarks of Mr. Crane it is very important to consider the horizontal motion of the axle when it is impelled upward. I believe I have mentioned that in my paper, and showed that the acceleration can be reduced, if means are permitted to allow the axle to move backward. In practice, as Mr. Crane mentioned, one method is to slope the spring, have the front spring-eyes higher than the rear. Another method would be to attach the front eye rigidly and shackle the rear end; this would permit a slight backward motion of the axle, when the clearance between the latter and the body is decreased.

DR. H. C. DICKINSON:—It seems unfortunate that a problem which is essentially so simple should be apparently so very complex. There are two elementary functions to be performed by the spring suspension. The springs separate a rear axle and wheel system from the body. It is important that the wheels remain on the ground as much as possible. They must, therefore, follow the irregularities of the road and to do this the period of vibration of the wheel referred to the body should be as rapid as possible. On the other hand, the body is required to have the least possible vertical motion; its period of vibration with reference to the wheels on the ground should be as slow as possible. This means the lightest possible axle and wheel system to respond quickly to road irregularities and the longest practicable initial deflection of the springs to give the body as slow a period as possible. It seems to me that Dr. Liebowitz has designed an ideal spring suspension. This supports the contention that really the fundamental thing is to have a considerable deflection of the springs to start with.

There is another point, however, which I believe is worthy of some discussion. Dr. Liebowitz has brought up a contention which, if sustained, is such an absolutely fundamental contradiction of all that we know about elastic bodies that I would like to hear further opinion on the subject. We have studied springs, as he says, for the last several hundred years, and know something about elastic hysteresis and so forth. Now elastic hysteresis exists and springs do change their characteristics after repeated stress, but the changes so far as we know are extremely small and it seems to me that he requires for the action which he has stated a sudden change, that is, a broken, irregular change in the resilience of the spring amounting to about 100 per cent of its original stiffness. If that is the case, it is absolutely contrary to our experience, because the changes in all these experiments which he has cited are usually of the order of a few parts in ten thousand, and none of them much greater, I believe. Moreover, springs are used for various purposes. For instance, the spring is used as a torsion suspension where the force is determined by the torsion of a spring wire and such suspensions are used at various amplitudes and in various ways. These things have been experimented upon for many years and found to give very consistent results, and no irregularities in their action resembling those shown by Dr. Liebowitz have ever been discovered so far as I know. Their restoring force has changed somewhat in some cases, but always in a smooth curve, not an irregular one. This same thing

is true of weighing mechanisms which involve very stiff springs under very heavy initial load, and in a great many other cases which I could cite, where the action of springs under both repeated stress and otherwise has been determined. We use them in our watches for hairsprings and the action of the steel is under repeated stress, even under stresses which are not very small. The behavior of these springs is always very consistent when we consider magnitudes of several per cent. In fact the consistency of the hairspring of a watch is a remarkable example of exact repetition of behavior which is hard to duplicate.

MR. SCHAFF:—I fully agree with Dr. Dickinson in regard to this phenomenon of spring fatigue after a short period. I think we should be careful about going on record as to any phenomenon of that kind. As far as I know, it takes a long period of constant use to fatigue steel. It is a more complex question than one of short use and complete recovery afterward.

J. S. MACGREGOR:—The question of fatigue for gradual fracture of metals subjected to alternate stresses as well as the question of their hysteresis is always of great interest to automotive engineers. A few years ago I conducted a number of experiments upon several steel bars. These bars had never been subjected to stress previous to tests, other than stresses which result from normal handling subsequent to fabrication. The testing procedure was as follows: A gage length was laid off, the bar subjected to a load well within the elastic limit and the elongation read. The load was then released, the set read and the rate of recovery observed. It was found that, regardless of the time a bar was allowed to rest, recovery to the original gage length was never complete. A new gage length was then laid off and the above cycle or partial cycle repeated; the new set was observed to be less than the first and the rate of recovery although not complete was more rapid. It was observed that the set decreases in magnitude and that the rate of recovery increases with each succeeding cycle, until ultimately the recovery is complete and its rate rapid and practically constant.

These experiments indicate that sound steel becomes more and more truly elastic under repeated stress, the structure apparently becoming oriented or trained to a certain range of load reversal. It would seem, therefore, that a spring should improve in service, if not overloaded, and I am surprised at the author's statement concerning lapses in recovery when repetitions of stress in a spring are rapid and continuous.

W. C. BAKER:—Contrary to Dr. Liebowitz' statement in regard to believing that the elasticity has been reduced, it seems to me it has been increased; that is, it has a greater property of elasticity after it has been continually vibrated.

Reverting to the matter of unsprung load, I believe that the automobile with its rapid speed is an entirely different problem from the ordinary horse-drawn vehicle at slow speed. The greatest gain in the riding quality of an automobile can be obtained by reducing the percentage of unsprung load. At high speeds the inertia of the axles and wheels is so great that their amplitude is far beyond the variation due to obstructions in the road. The increased motion is partially imparted to the sprung load, causing extreme bouncing. It is very hard to get springs that will ride easily over cobblestones at slow speeds and at the same time ride well at high speeds, particularly with cars having a low ratio of unsprung load to sprung load. Reducing the unsprung load is our principal problem. The ideal would be unsprung load, zero, no weight whatever. The nearer we approach such a condition, that is, the less the percentage of unsprung load to sprung load, the easier it will be to make an automobile ride well at high speeds.

F. E. MOSKOVICS:—In the Vanderbilt Cup racing days we had a car weighing 2204 lb. Sometimes we had to shave the tires to get down to that weight, but that is what the car weighed. I believe that no cars are raced today over rough tracks like the old Vanderbilt course; there is no modern race course like it. The record Lancia made, up to the time he was wrecked on Long Island, has not yet been approached. His car had, perhaps, the lightest unsprung weight of any car I have ever seen in a race; it had a solid-axle and was chain-driven. In regard to balance, I remember that when the first foreign cars came over, the foreign racing men would place their cars on the scales and weigh them very carefully with the front and the rear ends loaded, including themselves, to get exact balance between the front and the rear end. They watched every relation between the unsprung and the sprung weights. Last year, in California, these things came back to my mind when one of the contestants in the Santa Monica race objected very seriously to the course because there was a bump in the road that raised him up 5 in. when he was going 90 m.p.h. I know that Lancia was going 120 m.p.h. over the rough Vanderbilt course, averaging 79 m.p.h. That was over ten years ago and it was possible simply because he had the best balanced car that ever entered the Vanderbilt Cup races.

MR. TILLSON:—The question was raised as to fatiguing materials; and two diverse views were expressed, which might possibly have been correlated. In the case of the springs considered we are thinking of sudden application and reversal of forces upon metal, a rapid acceleration from one state to another state. In the other case, an example might be given to illustrate the remarks of a later speaker who called attention to the fact that springs can be used over long periods of time, involving the consideration of the well-known torsion-pendulum clock in which a mass oscillates around a vertically suspended slight spring. Such a spring undoubtedly makes the reversal of stress many millions of times before it fails by fatigue. I have one of those clocks that has been running for twelve years, and I never had the spring fail from fatigue, but the function of the pendulum is to assume gradually a state of rest and to be stressed gradually in the opposite direction. On the other hand, if we consider the stresses applied in the rock-drilling art, in which pneumatic tools strike a bar of drill steel possibly 1500 times per min., any of the blows of which is far less than the elastic limit of the metal of the drill steel, we find that within a short period of time that steel will fail. The nature of the failure is very certain; the appearance of the fracture will be conchoidal; it will show a growth from a small point of fracture, by gradually expanding layers such as we see in shell, to its final rupture of the entire section of the steel. That is an instance of suddenly applied stresses in a metal which cause, as has been indicated by microscopic examinations, a gradual weakening of the bonds of the molecules of the material. They form initially what is known to the metallurgists as "slip planes." These are planes of fracture through the molecules which are so microscopic as to be lost in general, but can be determined if a specimen is polished prior to being subjected to the stresses.

The same thing was demonstrated six or seven years ago by the investigations of Dr. Dudley into the failure of rails for steam railroads; the pounding of the car

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wheels on those rails causes them to fail; the fractures are exactly similar to those which I mentioned in regard to drill steel. The fact that we can run a clock spring for years with millions of reversals of stresses does not indicate that we can expect the same service from another spring which is given suddenly applied stresses.

MR. CRANE:—I have ridden in the Knox single-cylinder air-cooled automobile, long ago, which used the old Concord wagon spring, the springs being even more continuous than they were in the Olds curved-dash runabout. In fact, the rigid points of attachment could not have been over 18 in. apart. The action of that car reduced to an absurdity the claim made for the long springbase, because it was a car with possibly a 90-in. wheelbase that had actually a springbase of 18 in. And it was an extremely good riding car, due to the fact that it had unusually soft springs for that day and correspondingly slow movement.

DR. BENJAMIN LIEBOWITZ:—Spring suspensions have always been a prolific source of discussion, and many papers have been written upon the subject. The problem is very evasive, much more so than a casual view of it would indicate. For example, a company which has been using semi-elliptic springs will change to three-quarter elliptic one year, to platform springs the next and then back to semi-elliptics. This summarizes the history of spring experiment and development with many automobile manufacturers. The difficulty is simply that we have hitherto been unable to pin down the exact defect in the present type of suspension. It was a long time before I found out just what this defect is and I suppose it will also take some time before the automotive industry, as a whole, actually realizes it.

We started our work with the assumption that spring steel is imperfectly elastic to a sufficient extent to give hard riding. Our first experiments in the laboratory in 1915 showed that this is not the case when the spring is new. These first experiments showed very clearly, however, that a radical change came over the spring after several hours of hard running in the laboratory, where conditions were much more severe than would be encountered under ordinary road conditions. We did not realize the significance of this result, however, until after our later experiment with trucks.

The claim has often been made that whatever change comes over the springs is due to inter-leaf friction, or friction in the shackles, etc. Quantitative analysis shows, however, that this cannot be the case when the springs have become so imperfectly elastic as to cause accelerations of 1½ times the force of gravity in going over a comparatively small bump. If the spring had functioned with perfect elasticity in this particular case, the acceleration would have been about 30 per cent of the force of gravity; inter-leaf friction, if it were causing the remainder of the acceleration, would have to so stiffen the spring that it would not move until a force equal to 1.2 times the load carried was applied. We know that such magnitudes of inter-leaf friction do not exist, even if a spring is rather badly rusted. Ordinarily, the inter-leaf friction may be as high as 20 per cent of the load carried. If we assume the friction to be as high as 20 per cent, then the total acceleration due to friction and to the spring displacement would be ½ of gravity in the case in point. Actually, on a new bus, we did get about ½ of gravity, but on an old bus we got 1½ times gravity. Where did this large additional acceleration come from?

We have been devoting much study to this question and find that the high accelerations are due to the imperfections in the elasticity of the steel, which are brought on by fatigue. Many points that have a bearing on this matter have been brought out in scientific literature. I wish to point out very clearly, however, that this question of fatigue has nothing to do with balance springs or watch springs or springs which are ordinarily used for measuring purposes, because in such cases the stresses are very low and the frequencies are either extremely low, or regular, or both. In the case of vehicle springs, however, we deal with high stresses of a rapid and irregular character. Anyone who has attempted to calibrate a steel spring or bar for purposes of measurement, using high stresses, can testify to the highly-irregular character of the results obtained.

I wish to raise one other question at this time, the possible effect of recovery. I have no proof as yet that recovery plays any important part in this matter, but there is some fairly good evidence that it does. It is a very common experience to go out on a day's drive on a fine morning, with the car riding splendidly, but after driving for a number of hours the car seems to ride very hard and the passengers get tired through and through. Of course, we have always attributed this phenomenon to bodily fatigue, but I am not at all sure, in view of some of our more recent experiences, that spring-fatigue may not have something to do with it. Dr. Dickinson spoke of observed changes of the order of tenths of a per cent, or less, in steel's elasticity. Permit me to call attention to the fact that even with the low stresses and low frequencies which Dr. Mason used, he observed changes of the order of 10 or 15 per cent in the amplitude of vibrations for a given applied force.

Turning now to some of the other points which have been raised in the discussion, other methods for measuring the vibrations of vehicle bodies have been cited. I believe I mentioned most of these in the body of the paper. There is one, however, which is new to me, the use of an elastic system having a very short period compared with the period of the body vibrations, and observing the motion of this system through a microscope. It seems hardly possible, however, that accurate reliable data can be obtained by this method. On the other hand, the use of the seismograph gives a full-size accurate visualization of the body vibrations, and an analysis of the curves gives the acceleration at any desired point. The seismograph can be used on any roads under all conditions, and to my mind is far more practicable than the optical methods. In fact, that was the whole reason for developing it.

The question of springbase versus wheelbase was raised. I have tried to indicate in the paper, using the simplest physical conceptions, why the distance on the frame between spring anchorages does not affect the riding qualities; only the actual wheelbase itself does this. As I have already indicated, this conclusion can be reached most simply by considering the matter from the standpoint of the quality of action and reaction. Perhaps the best experimental proof is the case cited by Mr. Crane, of the old runabout which employed a continuous spring running from front to rear, in which the effective distance between the spring anchorages on the frame was about 18 in.

A number of other questions were raised, such as the effect of unsprung weight, fore-and-aft flexibility and the balance of the car. These matters are rather outside the intended scope of my paper. The primary object of it was to point out the methods available for measuring vehicle vibrations and to incorporate a sufficient amount of the theory involved to enable a proper interpretation of the measurements to be made.

ADAPTING ENGINES TO THE USE OF AVAILABLE FUELS

BY J. G. VINCENT

SOME of the salient facts regarding the character of the engine fuel marketed within the past few years are shown in accompanying curves. The desirability of operating present-day experimental cars with fuel that is the equivalent of fuel that will probably be generally marketed two years hence is stated and various methods of meeting the fuel problem are then examined. A dry fuel mixture is desired to prevent spark-plug fouling, to improve engine performance in cold weather and to minimize lubrciating oil contamination by fuel which passes the pistons. Various methods of obtaining a dry mixture are then discussed, leading to a detailed description of the construction and operation of a device especially designed to accomplish such a result more successfully. In principle, this takes advantage of the difference in pressure existing on either side of the carbureter butterfly-valve and causes a small amount of the combustible mixture to pass through a passage parallel with the main carbureter passage. This mixture is then burned in a suitable burner and the burnt gases allowed to mix with the incoming main supply to the engine above the throttle. This gives maximum efficiency under low throttle and light load conditions. When high volumetric efficiency of the engine is desired under wide-open throttle conditions, very little mixture passes through this shunt passage and a negligible amount of heat is produced in the burner.
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THE DISCUSSION

H. M. CRANE:—My first impression was that we had here another cylinder added to a crankcase that was already somewhat overcrowded. That is not entirely a humorous conception. The necessity for devices of this kind is a function of how good the inlet manifold itself may be, combined with the carbureter or vaporizer. Our experience through a great many years has indicated that an inlet manifold which does not continue in an upward course practically the whole way from the carbureter to the cylinders is a far more difficult proposition to handle than one in which such a condition holds. The reason is quite plain; we have the effect of gravity working on the heavy fuel, which is almost always present as a liquid in the mixture, in addition to the effect of the air-stream. If we have a sufficient air-stream to carry the liquid fuel, the distribution is relatively easy. The minute the air-stream falls to such a slow speed that other elements enter, the distribution is almost impossible, but by getting an ascent of the mixture from the carbureter to the engine the gravity interferes less with the air-stream.

On the other hand, I think that the device described is a very interesting example of the conception that the way to warm up an engine is to use a little fuel especially for that purpose, rather than to use the whole engine itself as a heater. I think that there is no question that we can get the results far more economically in the way that is shown in the paper, than we possibly can by any system which involves operating the engine until various parts of it become warm enough to do the work. The only thing that is apt to be complicated by a device of this kind is the idling condition of the engine. We all know that to idle an engine properly, where the inlet manifold will show nearly 20 in. depression of mercury, the slightest leak in any place is almost certain to upset the conditions, and here we have a continuous leak of burnt gas into the manifold, practically past the throttle, which is certain to make the idling situation more difficult than it already is. It is possible, of course, that the addition of the extra heat will tend to overcome the conditions raised by the very heavy fuels which do not vaporize well at the slower speed, i.e., the air speed, that obtains under idling conditions. There is no question either, from the layout of this drawing, that the device has been very carefully worked out and applied in a way that is probably about as near correct as is possible on this particular job.

R. W. A. BREWER:—In one part of his paper Mr. Vincent says that he wants to get 100 per cent of heat transference from the heating means to the fuel and air-stream. I rather wonder why he did not burn the fuel inside the air-stream instead of outside. That has been done in many cases. I recall the work that was done by the Commercial Cars, Ltd., of London, for example, about 1913, where a very crude attempt was made to provide that previous high temperature zone which is so desirable and so necessary in any system which we must adopt at the present time, working along Mr. Vincent's lines.

There are two ways of investigating this problem. One is the way propounded, in which we have a sufficient zone of high temperature, which should not for a moment be confused with the question of quantities of heat. The second is to treat the fuel and air mixture so that liquid does not pass through into the engine cylinders. What we are aiming at, in order to obtain the best results, is a dry mixture in the engine cylinders. If that is accomplished, a great many of our problems disappear. To obtain this dry mixture, Mr. Vincent has resorted to the locally-heated system. We must bear in mind that local heating is a question of supplying at the right place a metallic surface, if need be, upon which certain fractions of the fuel, and those only, can impinge. He rather decries the work of others in that field, when he states that certain attempts have been made by design, etc., to localize these areas of high temperature with a view to attaining a certain end. I believe these areas can be localized, and I believe that the design of the pipe can be such that the desired end is attained. It seems not to be so fully understood as it should be, that fuel in suspension in an air-stream does not lie homogeneously throughout the air-stream. The previous speaker referred to the question of carrying liquid in suspension at a sufficiently high velocity. If we could do that everything would be well, assuming, apparently, that the liquid particles were distributed in a homogeneous mass throughout the stream, which of course we know is not the case.

An important point in connection with manifolds of this type, when we can obtain a dry mixture, is that the effect of valve-timing is not at all serious. We have seen great research into variations of valve-timing and one often notices on drawings the valve-timing specified to degrees and fractions of a degree. I think it is rather straining a point when the system is pursued to that very great degree of fineness, because the effect of the intake manifold is very much greater than the effect of any sort of valve-timing, or a great many other problems such as

valve areas, which have been foremost in automobile thought for some time. For example, the effect of turbulence is very important and should be considered most carefully in the design of an engine. We have previously had a little sidelight thrown on this question of turbulence, and it should be borne in mind very strongly by men who are considering the whole of this problem. Unfortunately, we find people side-tracked along one line of thought; they neglect altogether certain dependent factors which are probably far more important than the one line of thought which they are pursuing. In any system of dry induction the only way is to consider all the factors concerned.

I call attention to some work I did a number of years ago, just to indicate one line of difficulty that has not been referred to by anyone else and that most designers of intake manifolds have not considered. It is the effect of the pressure existing in the intake manifold at the various branches or at the various valve-pockets during the sequence of operations. One goes to very great length, for example, to balance an engine mechanically, oblivious apparently of the fact that the great disturbing factor of the whole problem is the variation of pressure in the individual cylinders. If one cylinder is charged with air and mixture at a certain pressure and the next one at a different pressure, we are quite aware of the variation of resulting explosion pressure and the effect that it has upon an engine. The pressure at these various points has not been taken care of by designers and the result is that when we have a mixture which is in a more or less unstable condition and subjected to variation of pressure, the gasoline which was previously just in suspension is squeezed out or absorbed in the way that a sponge would operate in a liquid. We may start off with a very fine set of conditions, but if we subject the mixture to variations of pressure and temperature at the wrong places, we are bound to upset the state of conditions which were at first produced by very great skill and effort.

In all discussions upon manifolds engineers seem to make a very casual statement as to the hot air; this mixture was heated, hot air was supplied, and so on. It is not hot air that we want. If we are going to make a dry mixture, of course a certain temperature has to exist or the liquid cannot remain in suspension as a liquid; it will precipitate out. But it is temperature, it is distillation and many other things which have to come into consideration with a complex fuel in order to obtain a certain stable set of conditions. With modern fuels, if we wish to obtain these stable sets of conditions, we must put the fuel into a state where it is able to adapt itself into the required state. Any amount of heat, if the temperature is not sufficient, will never do any good and may do harm.

One other point is that far too much thought is given to the question of mixture of maximum horsepower at maximum engine speed, etc., which is referred to by Mr. Vincent. I think we must sacrifice something, because after all an engine very seldom runs under maximum conditions. We must give a man an engine that operates well with the device provided, under the normal conditions of working to which he will subject this engine.

W. G. WALL:—One thing, already mentioned by Mr. Vincent, seems of very great importance in laying out manifolds; that is to see that the gas does not cool off again after it is once heated. It is rather difficult to accomplish this unless the manifold is inside the cylinder or head. Theoretically we would like to vaporize the gas and then cool it to a point where it is still vapor, but where we get the maximum power. That would be very difficult of accomplishment, especially under varying speeds and loads. Another point in regard to the hot-spot brings up a little experiment I conducted not long ago, in regard to the shape of the manifold and the difference in heating the mixture as to whether the hot-spot is on the bottom of the pipe or in some other position. I think most of us would say that at low speed of the gas the hot-spot should at least cover the bottom of the intake manifold; but by simply making a slight bend in the shape of the manifold so that the gas went direct against the hot-spot, exactly the same object was accomplished, even at low speed of the gas. Therefore, it is a question in my mind whether one of the greatest items is not the shape of the manifold. We are familiar with the experiments conducted in regard to designing the shape of manifolds, so that at slow speed the gas comes in contact with a hot-spot and at high speeds gets farther away, due to the velocity of the gas through the pipe. That seems to work out fairly satisfactorily.

What is Mr. Vincent's idea relating to the heating of the gas after it enters the cylinder and the appreciable difference in horsepower between a water-jacketed combustion space and one that is only partially water-jacketed or not jacketed at all? To my mind, when the combustion chamber is only partially jacketed, even during the small time the gas remains in the cylinder it becomes heated to such an extent as to reduce considerably the horsepower otherwise obtainable.

H. C. GIBSON:—If the miniature carbureter described only delivers a negligible quantity of heat to the mixture under wide-open throttle conditions, I believe it falls short of a full solution of the problem, especially as it cannot aid in preparing for combustion such fuels as boil at very high temperatures. As an aid in starting and general operation under low throttle, the device has evident value, especially because it provides heat just where and when wanted without the introduction of combustion or indirect methods. The consumption of gasoline for this purpose is justified. I take issue with Mr. Vincent that a heater to be practically out of action at wide-open throttle is the condition to be desired. If economy is desired, the heater should be very much in action preparing the liquid fuel for conversion into the dry gas which is distinctly and properly favored throughout his paper.

A tight-fitting choke will aid in pulling a solid stream of liquid gasoline from a nozzle, but I believe that one phase of the solution of easy starting is to furnish a special choking throttle at the carbureter nozzle whereby maximum air speed past the nozzle can result in maximum agitation and atomization of the fuel. Such a throttle should be used only in starting.

It is true that we are all striving to get the greatest possible power out of the smallest engine, and I agree that it is hard to swerve established custom, but it will be easier to overcome popular trade objection to the use of exhaust heat when it is realized that with such heat controlled to meet the demand for vaporization we have a much more satisfactory engine for all-around utility, economy and power developed per pound of engine weight, if we take advantage of modern ability to produce long-lived high-speed engines.

DR. H. C. DICKINSON:—Mr. Vincent's paper presents for consideration one very practical suggestion for the solution of the problem of heavier fuels. The mixing of freshly-burned hot gases with the intake is unquestionably a very effective means of heating, without the delays incident to heating the manifold or water-jacket.

The ingenious design of the device whereby the extra fuel is burned and the extra heat supplied only at partial throttle, in about the desired amounts for good operation, is most interesting. The author is rather modest in his claim regarding overall economy. Considerable improvement in mileage might be expected under all but hot-weather conditions.

Referring to fuel characteristics, while it is quite true that no one characteristic of a fuel can determine its suitability, there are three characteristics which together very nearly determine the value of petroleum fuels, provided only that these are reasonably free from injurious foreign substances. These are the initial boiling point, the end-point and the mean volatility; in other words, the entire distillation curve of the fuel. In the chart showing variations in gasoline from 1916 to 1919 inclusive, the author gives figures for initial point, end-point and specific gravity. It has been pretty generally accepted that specific gravity has no longer any direct relation whatever to fuel gravity. A curve giving mean volatility in place of specific gravity might therefore be more useful.

As regards increasing the power of the Liberty engine by decreasing the temperature, the charge weight is about inversely proportional to the absolute temperature; and it is almost invariably found that the increase in power when the temperature is lowered is much less than would be computed from its increased weight of charge. To get an increase of 20 per cent in charge weight would require a decrease of more than 100 per cent in air temperature, and from all available data this would not give by any means an increase of 20 per cent in power unless a change in fuel makes a considerable difference in power, independent of temperature. A large number of tests have been run in the altitude chamber of the Bureau of Standards, in which the temperature of the intake air has been changed repeatedly by nearly 100 per cent, with a corresponding change in horsepower very much less than 20 per cent. A change in fuel from commercial gasoline to aviation gasoline may, however, make a difference of several per cent in power without change of temperature, particularly if the carburetion is not very good.

In reference to spark-plug fouling, it is suggested that the presence of fuel on the sooty deposit on the spark-plug insulator may render this layer conducting. As a matter of fact, gasoline and kerosene are excellent insulators, being about equal to the heavier oils, and should tend to improve the insulation rather than act as conductors. On the other hand, possibly the heavy ends of the fuel absorbed in the sooty layer crack and oxidize on warming up, thus adding to the amount of carbon. Is it not possible that the maintenance of a reasonably lean mixture, or a mixture which is lean at usual driving speeds and loads, will entirely prevent fouling? I am quite satisfied from personal observation that this will result even when wet mixtures are used.

F. C. MOCK:—The question of the temperatures needed for a dry manifold at different throttle positions is of interest. From observation I would say that with our present gasoline of 430 deg. fahr. end-point and about 300 deg. fahr. mid-point, the manifold will be dry when the engine is idling; somewhere between 80 and 100 deg. fahr. But to get it dry at wide-open throttle requires from 180 to 200 deg. fahr.; in fact, I have never got it to look dry in any apparatus I have had in use.

I am not sure that it is desirable to have the manifold dry. I think we can get the limit of good operation without having it dry at wide-open throttle; but everything we have tried which brought a satisfactory condition at wide-open throttle, gave enough heat at closed throttle. Practically all of our difficulties are encountered at wide-open throttle, particularly at low manifold air velocities. All the experiments we have made indicate that a properly-designed application of exhaust heat to the intake will give a uniform rise of temperature to the mixture passing by it, regardless of load or engine speed. There seems to be a sort of natural automatic regulation, the heat present in the exhaust being fairly proportional to the amount of fuel passing the heating surface.

E. D. THURSTON, JR.:—In regard to the burning of the mixture in the heater, how is the combustion started? I have had some experience in burning explosive mixtures and believe that any delay in starting combustion in this heating device will cause combustion to be set up in the main inlet manifold. Similarly, any interruption in the burning of the mixture in the heater, followed by subsequent combustion, will cause the same effect. It may be that this is a detail that has been worked out, but I should like to know how it has been accomplished. Mr. Vincent has based his calculation as to the heat necessary upon the effect taking place at constant volume; whereas it will actually occur at constant pressure, requiring about 40 per cent more heat.

J. H. HUNT:—The desirability of cooling the products of combustion of the burner before mixing them with the carbureter mixture has been brought out. In some experimental work with a similar device, it has been very interesting to have a window through which one can look into the manifold. With such an outfit in operation I have seen a red flame project into the manifold at least ¼ in. without igniting the mixture entering the engine. This was under wide-open throttle, as the arrangement of the window did not permit viewing the conditions at partly-open throttle. Obviously, with partly-closed throttle and greater suction, the flame would project further; and even under these conditions the mixture is not ignited. It is not easy to account for this failure to ignite, but very evidently it is not necessary to cool the mixture as much as one would suppose.

Such an outfit may not be ideal, because relatively very little heat is supplied under wide-open throttle conditions, as has just been pointed out, but our troubles today come mostly from driving the engine choked when first starting, and when the engine is cold. A device of this type, which will accelerate heating the engine and also heat the mixture while the engine is still cold, reducing the use of the choker to a minimum, will very greatly improve the conditions with which we must contend. While in the ideal solution it may be necessary to supply more heat for wide-open throttle work, particularly for lower-grade fuels than we have today, the device which already exists takes care very nicely of the conditions we have to meet in automobile engines. Possibly for a tractor engine more heat would be needed at wide-open throttle, because most of the work is done at or near wide-open throttle.

PROF. O. C. BERRY:—I wish to add what emphasis I can to Mr. Vincent's statement that it is time that we devise some system which will insure the realization of the entire useful life of the cars we are designing today. It seems to me inevitable that the fuel to be sold a few years hence will be so much less volatile than our present gasoline that many of the cars built and sold this year will be unable to carburet it successfully. The need for a larger fuel supply is so pressing and so widely understood that some one is reasonably certain to develop a successful way of using more nearly all of our crude petroleum for engine fuel. When such an invention is made, its adoption will be rapid and the petroleum in-

dustry will quickly take advantage of the opportunity to change the quality of the fuel put upon the market. Since no one can now predict just what form this invention will take, it might be well to have the intake manifold a separate casting, to give the owner every possible chance to install on his car the inventions of the future and thus be able to get satisfactory service until his car has worn out.

A number of tests carried out at Purdue University are of interest in connection with the question of whether a dry mixture is to be desired in the intake manifold. A Willys-Knight engine was used, mounted on a Diehl electric dynamometer. Except for the small amount of heating through the walls of the short water-jacketed intake manifold, all of the heat for vaporizing the fuel in the mixture was supplied as sensible heat in the air entering the carbureter. The temperature of this air was changed by small steps from 60 to 300 deg. fahr., and the cooling water was kept at about 200 deg. fahr. Under these conditions the engine would not run properly with the 60-deg. air when using gasoline having a gravity of 56.5 Baumé. When the air temperature was raised to 71 deg. fahr., the engine ran more smoothly and gave better power, but still did not operate as it should. With 80-deg. air the operation was satisfactory, except when the leaner mixtures were being used, and the power and efficiency were the highest we were able to obtain. Air at 100 deg. gave about the same power and efficiency as 80-deg. air, but each increase in temperature above 100 deg. caused the power to decrease considerably, and the efficiency slightly, until with air at 300 deg. the power had dropped 22 per cent and the efficiency nearly 1 per cent. When the air entered the carbureter at 275 deg. fahr., the mixture was quite dry as was shown by its appearance as it passed through a glass section in the manifold, but lowering the temperature much below this point would produce a fog in the mixture.

To my mind a distinction should be made between requiring a mixture to be dry in the intake manifold and dry at the end of the compression stroke. The latter seems to me to be the essential requirement. Even though wet mixtures do lead to distribution troubles when the manifolding is poor, a mixture that is not too wet can be satisfactorily distributed by a good manifold. The piston-head is hot enough to vaporize a small amount of liquid fuel deposited on it by a wet mixture, and the fog of liquid fuel that remains suspended in the air will be vaporized by the heat of compression. In the Purdue tests the best results were obtained with mixtures that were wet in the manifold. These wet mixtures gave a smooth running engine, a clean exhaust, about 20 per cent more power than the coolest dry mixture and a slightly better efficiency.

Too wet a mixture will cause the engine to miss, and lead to loss of power and efficiency, dilution of the lubricating oil, sooted cylinders and spark-plugs and other serious troubles, as was demonstrated by the Purdue tests run with the 60-deg. fahr. air. This would not, however, lead one to the conclusion that a dry mixture in the intake manifold is the ideal condition.

SYDNEY BEVIN:—One of the members has suggested that the knock in an automobile engine using kerosene or other fuel which produces a typical knock other than the preignition knock, might be caused by the molecules of gas in the exploding mixture vibrating through such an amplitude that they struck each other and that the kinetic energy of these molecules is therefore transmitted very suddenly to the piston and cylinder-head, as would be the case if a mass of gas were detonated in the cylinder. My thought on this subject is that a fuel, such as kerosene or fuel oil, would split under the heat and pressure of compression into three or four explosive gases, and perhaps one liquid which will not volatilize; that the kinetic energy of the exploding gases is transferred to the droplets of the unvaporized liquid, which in their turn strike the piston and cylinder-head and transmit shock. It is rather difficult to picture the gas molecules traveling at sufficient speed to produce a knock, whereas the droplets of the unvaporized part of the fuel would be able, owing to their superior mass, to strike a more violent blow. The addition to the fuel of some iodide, as demonstrated in the experiments with different fuels in the discussion of indicators for high-speed engines, might lessen the tendency of the kerosene, or fuel oil, or other fuel, to form the droplets mentioned, thus tending to eliminate the cause of the knock.

J. G. VINCENT:—You probably realize that there is much in what Mr. Crane says about the matter of keeping the mixture going up all the way into the cylinders in this particular job. Frankly, I think this sort of device is of more value in a V-type engine than in a vertical type, although I have worked it out in various types of engines and have failed to find any engine which it did not improve. Of course, it is easier to apply the device to some engines than to others. For instance, with a vertical engine it is possible to arrange the carbureter so that the extra mixture for the burner is taken off the first bend above the carbureter, so that the auxiliary vaporizer is done away with. I mention this as something that can be accomplished under certain conditions. The particular installation that I have shown in the drawings did not lend itself to that form of construction.

We found in early experiments some difficulty in making the engine idle with this device, as well as without it. A little later we obtained results that were slightly better than we were able to get without it. The important thing in getting good idling seems to be to have this burnt mixture come in at the right place with relation to the incoming charge. In the drawings I have shown it coming in at two different sides. It may be better, under certain conditions, to have a sleeve arranged so that the burnt gas will come up around it and form a sort of envelope around the incoming mixture.

Mr. Brewer thinks it would be better to apply the heat on the inside, so as to avoid losses. That is entirely possible and it may be a good idea. It is not one with which I have experimented and it probably presents some difficulties in construction, but it is certainly a good thought.

Mr. Brewer spoke of my decrying the so-called hot-spot manifold. It was not my intention to do so; I simply wished to point out what I think are its limitations. I understand that all these devices have their limitations. It seems to me that the difficulty with the so-called hot-spot is that it does not get hot quickly enough, or stay hot enough under idling conditions. Since I wrote this paper I have had a fair chance to check it up and see if what I said was so, because at that time I had not had a chance to operate under severe cold conditions such as 5 deg. below zero and the wind blowing on the car all night. I am glad to be able to advise you that the device operated exactly as it was supposed to operate. It started up promptly and after taking about enough time to back out of the garage and turn around and close the doors, about 2 min., I could drive out of the yard with the mixture set as for normal summer conditions, and jamb the throttle clear to the floor-board. This is a result, you will all recognize, that is somewhat hard to obtain under present fuel conditions.

Mr. Brewer stated that distribution is probably more important than the balance of the engine parts. I wish to concur thoroughly with that thought. I have been all through the subject; it took me a long time to realize that we were really doing many things in connection with balancing engines that did us no good, because we spoiled them all by spoiling the distribution. In comparing two engines, just as often as not the engine that was out of balance showed the best because of the distribution.

I agree that the engine output at high speed is not of paramount importance. I simply wished to state that it is important to keep as much of it as we reasonably can.

In regard to Mr. Gibson's remarks about the necessity for heat at higher speed, I am uncertain as to how far we must carry heat up the range.

Prof. Berry's remarks about the hot piston are of course pertinent. We know that we get splendid operation at high speed under wide-open throttle conditions without this heater. The hot piston will, I believe, take care of the vaporizing of the fuel after it gets into the cylinder. This does not help distribution. Some things are not yet definitely settled. However, in handling the condition up to 30 m.p.h., under steady-throttle conditions, we probably have taken care of at least 80 per cent of the driving, and that part of the driving which certainly gives us the most trouble.

In regard to Dr. Dickinson's remarks about fouling spark-plugs, I have not had time to investigate just what caused the fouling. I do know that we have blamed a lot of fouling of spark-plugs upon oiling, when the oiling had something to do with it, but wet mixtures a great deal more. With the mixture properly dried out we do not have any spark-plug trouble, whereas we formerly had considerable. I do not know just what happens.

In regard to my statement about the choker-valve fitting tightly, it is of course important to have a slight leak past this valve at the lowest point, so that the gasoline raised out of the jet will run down to the orifice and meet the high-speed incoming air and be broken up. That is the only way I have found to get good starting. Naturally this can take a large number of materially different forms.

HIGH-SPEED INDICATORS

BY THOMAS MIDGLEY, JR.

THE indicator was an important factor in the early development of the internal-combustion engine when engine speeds were low, but on high-speed engines such indicators were unable to reliably reproduce records because of the inertia effects of the moving part of the pressure element. The first need is for a purely qualitative indicator of the so-called optical type, to secure a complete and instantaneous mental picture of the pressure events of the cycle; the second need is for a purely quantitative instrument for obtaining an exact record of pressures. The common requirements for both are that the indicator timing shall correctly follow the positions of the crank and that the pressure recorded shall agree with the pressures developed within the combustion space. Following a discussion of these requirements, the author then describes the demonstration made of two high-speed indicators, inclusive of various illustrations that show the apparatus, and comments upon its performance. In conclusion, a description is given of a high-speed diaphragm indicator of the balanced-pressure type, developed at the Bureau of Standards. [Printed in the April issue of THE JOURNAL.]

THE DISCUSSION

A MEMBER:—Is the fluctuation of the curve due to the inertia of the instrument?

C. F. KETTERING:—There is no question that the curve is a composite of a set of conditions. In other words, you simply strike a condition during combustion which is not dissimilar to taking a plank, sticking the end out over the beam, pulling the end down and letting it wiggle. Part of that may be due to the inertia of the indicator, but nevertheless the different kinds of fuel will write their names down in fairly good shape. We know that the fuel in there changes its constants, whatever they are.

H. L. HORNING:—I agree that its vibrations are more a characteristic of the fuel than of the inertia of the instrument; although our instrument is supposed to have great inertia, the change of fuel has more to do with it. I will say, further, that the fuel and air have much to do with it and so has the temperature; it is primarily a chemical phenomenon.

THOMAS MIDGLEY, JR.:—I agree with Mr. Horning; the vibrations change with the mixture.

A MEMBER:—What does benzol do?

MR. MIDGLEY:—It gives a different characteristic, a smoother one, with a flat top on the curve.

A MEMBER:—Can you put in some kerosene and some crude oil?

MR. MIDGLEY:—We are now running in some fuel oil. It will take a few seconds to clean out the gasoline that was in the pipe leading to the mixture valve; then we will get the fuel oil there and you will notice that the curve will change very decidedly.

Now it is coming, you see it starting to peak up on the screen. As the engine warms up, this will become very much more intense. You see it is coming up more and more sharply all the time. To save time we will pass right on; the next fuel will be ether. This is extremely volatile. I think this one demonstration will disabuse your minds that knocking is in any way connected with volatility. If the engine is warm enough, we need no ignition to run on ether.

I now wish to show some genuine preignition with no knocking. We will put in some carbon-bisulphide. After the carbon-bisulphide is put in and it begins to get through the mixing valve, notice the early rise of pressure and that there is no knocking associated with this. As the early rise of pressure gets over to the left side of the screen, the engine will spit back through the intake valve, showing that preignition is actually so early with this fuel that it preignites before the intake valve is closed. From this demonstration it is seen that knocking is not associated with preignition.

The engine is now operating on benzol, which is a

compound quite different from what we have thus far run in the engine, as to its chemical nature. There is no trace of knocking whatsoever with benzol.

Now we are running the engine on alcohol, which is the smoothest burning fuel of any we have.

A MEMBER:—Can you tell us the principal characteristic of alcohol?

MR. MIDGLEY:—The principal characteristic is the smoothness of the combustion, the absolute lack of any indication of knock whatsoever.

A MEMBER:—With what maximum compression have you tried alcohol?

MR. MIDGLEY:—Two hundred and twenty-five pounds.

R. W. A. BREWER:—Do you think if you ran it up as high as 300 lb. compression, you would produce a knock?

MR. MIDGLEY:—No, I think not. I wish to show how we can take the knock absolutely out of fuel oil, while the engine is running. We will keep the spark advanced and everything right up on the engine, full power, proper mixture, everything the same. We will then take the knock out of the fuel oil. The engine has been purposely put out of adjustment in order to make the fuel oil knock in it. We have a special carbureter to jam up the power and purposely advance the spark beyond where it belongs. We also have some carbon in the cylinder-head to make the engine knock; the engine does not knock under normal operation.

You can now see the knock coming in on the screen. I wish to take it out for you. You observe that the engine is knocking violently. Now, by adding a drop of this liquid to the mixing valve you will see that the knock has entirely disappeared. That was done with one drop of ethyl-iodide. I will now show the same effect by putting in two drops of anilin; you can see the knock disappear and will appreciate that it was done with a very small amount of material added to the fuel.

MR. KETTERING:—Perhaps I can clarify a few things and so help to concentrate the discussion. This indicator was worked out primarily from the standpoint of fuel studies, simply to see how the fuel worked. It was only about eighteen months ago when we heard some papers read in which the kerosene knock was attributed purely to preignition. The chairman made a very significant remark when he said that perhaps we have not been trying the right kind of thing. That is correct; we found out that what we thought about this was not right. After we had read all the literature we went the other way. This indicator was developed primarily for that purpose. It is not intended to be a precision instrument, but is simply something with which we can use the different kinds of fuel and run all day long. It is just something that you can sit and look at that you never saw before.

This demonstration and those fuel diagrams show only some of the work that has been done. We have proved absolutely that volatility has nothing to do with knocking, and have demonstrated that the molecular structure of the fuel determines this. The dropping in of a little bit of ethyl-iodide or anilin was only to show that a very small quantity of material added to the fuel can change the whole nature of the combustion. With regard to the present fuel situation, it is just about like this: someone discovered some three or four hundred years ago that sulphur, saltpeter and charcoal, mixed together, made gunpowder. That was a great invention, but it was three hundred years before anyone thought it possible to determine whether the pressure in the gun barrel was right; then they began to find out it was not right; that black powder was not right. They then made all the various high-explosive powders and a gun to-day shoots a great deal farther, makes much less noise, and has less recoil. None of these indications, none of these physical things that we have regarded as being essential to a gun, have had anything to do with it. We find that by proportioning the powder right, we get a normal acceleration of the bullet.

Our theories to-day are just as accidental as black gunpowder; we are using just the fuels which normally come from the simplest type of distillation of petroleum products. We have taken the stuff that has been handed to us, without a question as to whether it is right or wrong. I think it is possible for us to make fuel where it is refined and introduce right into the refining of fuels the anti-knock that is necessary to change that fuel. We cannot influence it by changing the chemical composition at the place of refinement, without trying to do it. So, the thing to do is to find out there how to fix that knock. The indicator enables us to clarify our minds and make the problem more or less quantitative. What we must do is to start at the beginning, recognizing that we have a problem. The fact is that we have two problems, wet and dry mixtures. I could make an experiment right here, refrigerating the air and burning kerosene better with refrigerated air, with the wettest kind of a mixture, than can be done with the driest kind of a mixture. You can stop an engine from knocking by refrigerating the air and not reduce the power; in fact, the power will increase. With the ordinary multi-cylinder engine we do not know what one is causing the trouble. We must alter the chemical composition of the fuel. I think that the oil people are doing that. It is within the possibilities that when we meet again a year hence we can burn these lower-gravity fuels. Think what it means to take the knock out of the fuel; the formation of carbon then becomes entirely secondary, the compressions being high enough to burn the normal lower-gravity fuel. If we can stop our former practices and go back the other way, there is no reason why we cannot put the engine compressions up where they belond and use smaller bores.

We have run many engines with insulated piston heads. With an ordinary engine and about 1/16 in. of mica sheet on top of the piston heads we need not care how hot they get. There is never a premature explosion. We can take a lot of liberties with the fuel if we handle it properly. With the sheet described on top of a piston head the engine is almost immune from carbonization, for the reason that carbon deposit consists of two absolutely distinct things, one, a lubricating binder which is segregated from the lubricating oil, and the other, deposited carbon which comes out of the fuel.

Mr. Vincent tried to foul the spark-plugs by feeding too much lubricating oil. If we can change the rate of combustion of the fuel so that we can put the compressions up, we will have simplified the whole problem and the progress of the internal-combustion engine will be unlimited. I am not worried about the fuel situation, if we can avoid clinging to the things which we now have. Kerosene is increasing in price because there are millions of kerosene lamps yet. The electric farm-lighting plants have not been in operation long enough to reduce their number. But there is a cut in there, and the limitations of kerosene oil for lamps are much narrower than those

for running an automobile on it. We can take liberties with automobile fuel, up and down, but we cannot do much with the kerosene cut for lamp lighting. We must avoid that and come down into this fuel-oil cut which is about 50 per cent of the total of the crude. There we can get a quantity of fuel, but we must refine it somewhat differently, so that we can burn out the carbon, etc. It is only by getting together and conferring like this that we will solve the fuel problem. When we can write it out on the blackboard in specific units, the problem is solved, because there are hundreds of persons who can take those individual units and go ahead with them.

With Mr. Vincent's heater many things must be considered. In connection with dry mixture, when you burn gas in a manifold that has fuel and air in it, you have changed the whole nature of the thing; there is the tendency to condense, and the vaporization and other factors are changed. For instance, if we feed water vapor we cannot recondense the water at 212 deg. fahr. A mixture with the exhaust gases plus steam does not condense as it would if with pure steam, for familiar reasons. So that burning some gas in the intake manifold right at the start produces a condition that has to do with distribution, which does not necessarily depend altogether upon the wet and dry element. Mr. Good made some very interesting experiments in this connection a number of years ago and found that introduction of exhaust gases into the manifold modified the combustion. By introducing fuel in a semi-burned condition the fuel knock can be eliminated.

When we think of the things we have not done, we realize that we are fortunate to have developed as much as we have, without knowing about the most important thing, the fuel. The automotive industry is a chemical industry. We have acquired information on every subject except the most important one, which is the fuel.

C. A. ADAMS:—Many years ago in France, Professor Bertelot made an elaborate investigation into the velocity of propagation of combustion in gases. He found that with a given initial pressure and a given temperature of ignition, or we might say vigor of ignition, there is a certain velocity of propagation; if the pressure or temperature is increased, the velocity of propagation is increased; but when a certain combination of pressure and temperature is reached there is an enormous jump in the velocity from about 200 to 2000 ft. per sec. This means a change in the method of propagation and may be visualized as follows: The increase of temperature accompanying combustion causes an increase in the amplitude of molecular vibration; i. e., adjacent molecules approach each other more closely and the combustion is handed on from one to the other more rapidly, until the amplitude of vibration reaches a point such that adjacent molecules actually collide, when the time element of heat transfer from one molecule to the next is eliminated and the combustion is propagated substantially at the velocity of the molecular vibration. Under these conditions the combustion becomes a real explosion or detonation, which is the cause of knocking in engine cylinders. It is like a hammer blow, as compared with the soft push of the normal combustion.

For every mixture there is a particular clearance below which the compression is sufficient, with the ordinary vigor of ignition, to produce knocking, i. e., a detonation, without preignition. In fact, this is the factor which determines the proper clearance for each type of fuel, since on the score of efficiency it is desirable to have the maximum compression possible without knocking.

Information is already available as to the critical temperature-pressure relations at which detonation takes place in certain gases and vapors, but not in many of the fuels now in use or in contemplation for internal-combustion engines. Is this not an opportunity for conducting research which would be of great value to the engine designer, the results of which would allow engines to be really designed rather than to be just allowed to happen? There are many other considerations affecting design, but this is certainly of fundamental importance and worthy of study.

Mr. Kettering is absolutely right in his estimate of the importance of research and I am glad to see that the Society is beginning to appreciate that importance. We will probably find that it will pay to start such research work, with a study of existing literature in the pure science side of the subject. We may find much valuable information already worked out by scientists who had no thought of its application to the design of internal-combustion engines.

P. L. SCOTT:—We have been working with a type of engine in which a carbureter and ignition system are not used, and have had some very astonishing results in the behavior of fuel, when admitted to the cylinder only when we wanted combustion to start. We have secured as many as ten waves of combustion, and by a simple change have stopped that entirely. On other occasions we have taken two widely-different fuels and been able to produce violent knocking and a number of waves on the indicator card in each case; then, by another change in the manner of admission of the fuel, we have reduced the phenomenon. This shows that there is a very wide field for development in this direction. The compressions are very low compared to Diesel-engine practice. The compressions that were used run as low as 200 lb. per sq. in., and the injection pressure of the oil fuel has run as high as 10,000. Has the speaker ever found waves continuing for more than five lengths on any specific card, or found as many as ten waves on a card?

H. C. GIBSON:—The greatest value of this lecture on indicators may be in impressing upon the minds of those who have looked upon the indicator as something of a nuisance, something to be avoided because of its complications and difficulties, the ease with which we can get indications of what is happening inside of the cylinder. After all, that is exactly what we have to do. We are today tending more and more to the division of the power among a large number of cylinders. Every time we add a cylinder we add another team-mate to the crew we already have, and we must investigate the qualifications of each member of the crew. If we merely take the aggregate performance of those members, we get an extremely poor answer as to performance. So it is with the dynamometer or with tests up a hill with a car; we have obtained only the results of the combined, not the individual effort. If we make a change of design or accessories, we perhaps get a result whereby 75 per cent of the cylinders give a better effort, while the remainder give a poorer one; but the net is 10 per cent better, the overall advantage satisfies us, and we let it go at that. If we investigated each member of the team,

we could develop the operation of each cylinder to maximum advantage. I feel that every manufacturer of internal-combustion engines ought to be equipped with apparatus of this character for that purpose.

MR. MIDGLEY:—I have a photographed card that I would like to show in reply to the query about having more than five wave lengths. With regard to investigating fixed gases and the introduction of acetylene, we have never done that, but we have made fixed gases knock by merely raising the compression. The relationship between volatility and knocking is off the indicator subject, but it has been investigated with the indicator, and we found that in the same homologous series there is an increase of knocking with the decrease of volatility, but there exists no relationship in volatility between different chemical series; as we have reason to expect, we do not find when we get down to where we have nothing but fixed gases to deal with, that we can get rid of the knock. (Slides were then shown to illustrate the pressure element of the Bureau of Standards' instrument.)

A MEMBER:—Does that pressure-head diagram tell any more than that the pressure is greater or less?

MR. MIDGLEY:—Not a thing more; it simply tells whether it is greater or less than the admitted pressure.

DR. H. C. DICKINSON:—It was thought that in a general discussion of indicators it would be very desirable to have a paper covering all that is new on the subject, and so a description of the Bureau of Standards' indicator was given by Mr. Midgley.

As to the reason for adopting this type of indicator, about two years ago we found it necessary to devise some means for getting records without getting near the engine. There are two reasons why the aircraft engine presents a problem that no other engine has presented, and one of these I will discuss briefly. The aircraft engine is light and is usually mounted on a flexible support. Therefore the engine itself vibrates with rather high accelerations. This makes it very difficult to mount any recording mechanism which must be rigidly connected to the engine. Although the difficulty might be overcome, there is another difficulty connected with the design of an indicator for a light engine which we have also overcome in this instrument. This is a more fundamental difficulty and one which, so far as I know, has not come into the literature.

Through the top of a cylinder-head, surrounded by a water-jacket and an outer wall, we insert an indicator with a piston of some moving part. The indicator piston has considerable weight and to reduce inertia effects it is necessary that the range of motion which actuates the recorder be very limited. Therefore we have a support rigidly mounted on the cylinder-head and a rather heavy moving part, the piston with a recording device of some sort which magnifies the relative motion between this support and the free piston one or two hundred times. This is very good as long as the cylinder-head itself is rigid enough, but suppose we consider the Liberty cylinder, for instance, where the thickness of material is cut down; then, whenever anything unusual such as a knock occurs in that cylinder, of course this cylinder-head itself flexes with very high velocity. Therefore the flexing of the head carries the supposedly solid support of this piston device with it and allows the piston to remain more or less stationary, acting in the same way as the seismograph. This effect probably occurs in the very violent vibrations which take place during knocking at least, and is perhaps also due to flexing of the cylinder-head under normal explosion pressures. I believe that these motions are not of sufficient magnitude to be of any consequence in the cast-iron cylinders which we usually encounter, but in very light constructions they are certainly a mechanical difficulty that has to be guarded against. In planning this design of indicator we must overcome that difficulty by replacing the piston by a very light diaphragm supported by corrugated plates, which are not only perforated but turned out in annular rings so that the only bearing surface of the diaphragm is represented by these rings, the other portions being undercut. There is very little contact between the diaphragm and the support, and yet the support is sufficiently good that a diaphragm 0.002 or 0.003 in. thick will withstand 600 or 700 lb. pressure and be sensitive to within 0.1 lb., or 2 or 3 mm. of mercury, at pressures down around 10 lb. vacuum.

In ordinary operation two things can be done with this indicator; we can use it with a telephone receiver and a pressure gage, or as an automatic plotting device with a cylinder rotating at crankshaft speed, using an ordinary indicator spring and pencil arm with an electric spark, so marking a paper on the revolving drum to record the steady pressure applied to the upper side of the diaphragm. For public demonstration we have substituted for the telephone a high-power announcer, and we have substituted for the pressure gage the working parts of the pressure gage, namely, the bourdon tube with a mirror attached to it, which throws a spot of light upon the chart, so that the pressure scale can be seen directly on the chart and the contact made in the telephone receiver can be heard.

When the pressure in the cylinder is lower than the pressure applied above, the electric contact in the telephone circuit is broken and nothing happens. When the pressure in the cylinder is higher, there is a contact between the diaphragm and the electrode in the telephone circuit; and if the one-point timer, which is also in the circuit, makes contact at any time during that portion of the stroke during which the diaphragm is in contact with the upper support, there will be a click in the telephone receiver. Therefore the method of getting the pressure at any particular point is to first set this timer at any desired point, say at dead center; we then vary the pressure over the diaphragm, first increasing it until the clicking begins to become irregular, that is, until we get an occasional break in the periodic ticking in the telephone. This is the lowest pressure which occurs at that point in the cycle; we then continue to raise the pressure until the clicking entirely ceases. That represents the highest pressure which occurs at that point in the cycle. We will now demonstrate this.

First we intend to show the range of maximum pressures which occur. This engine is adjusted so that it is operating very irregularly; therefore there will be a very wide range over which the maximum pressures occur. We shall not attempt to use anything except gasoline and will show the method of getting the pressure which occurs at some specific point in the compression or explosion strokes of the cycle. Then we will plot a diagram which I think will prove very useful with this device, a low-pressure card of the intake or exhaust or compression stroke, as desired. The electrical current is now passing through the diaphragm.

HERBERT CHASE:—What is the object of the central hollow tube at the cylinder connection?

DR. DICKINSON:—The object of the hollow tube or the series of small tubes is to cool the gas to some extent on passing through the water-jacket before it reaches the diaphragm. That is not essential, but it was incorporated in this design.

DILUTION OF ENGINE LUBRICANTS BY FUEL

BY G. A. KRAMER

ENGINE lubrication troubles resulting from the dilution of the lubricating oil in engine crankcases appear with increasing frequency, particularly where economy demands the use of cheap grades of fuel. Unless a lubricant not miscible with present engine fuels can be produced, lubricants will steadily decrease in viscosity whenever fuel finds its way into them. The most satisfactory remedy is to prevent dilution of the oil. To prevent absorption of the fuel by the oil is a problem of engine design. In experiments made by the Bureau of Standards the absorption of fuel vapors at average engine temperatures was found to be negligible; further experiments and oil tests showed no indication of dilution due to cracking, with representative refiners' products from typical crude oils available in this country. Information was necessary relative to the effect on the viscosity of lubricating oils of their dilution with varying percentages of fuels; the maximum temperature to which they can be raised without serious deterioration when exposed to the air and to their own vapor, and the maximum temperatures to which they must be heated to remove the necessary proportion of the fuels they contain. A series of experiments made to determine the effects of fuel admixture on oil viscosity is therefore next considered and this statement is supplemented by additional data and discussion relative to distillation methods for removing the fuel from the oil. Several further experiments were carried out to indicate possible improvements through simple changes in distillation methods, relative to time of heating and area of free surface exposed. The ultimate solution of the problem is believed to lie along the line of new departures in engine design that will prevent the accumulation of liquid fuel in the cylinders and in the lubricating system. In an appendix suggestions are made advocating the use on existing engines of some self-contained device for restoring the viscosity of lubricating oils, with some details regarding the features such a device should embody.- [Printed in the February issue of THE JOURNAL.]

THE DISCUSSION

NEIL MACCOULL:—The dilution of lubricating oil is such a common complaint with kerosene-burning engines and even with engines burning the present-day commercial gasoline, that it is a subject worthy of thorough study. I am particularly glad to hear Mr. Kramer's refutation of the false impression entertained by some, that the thinning of oil in service is caused principally by cracking rather than by dilution with fuel.

It is natural that lubrication engineers should be among those most interested in an investigation of the causes and effects of dilution, and accordingly the company with which I am connected has been conducting somewhat similar research, although the study was made from a slightly different angle. Our experiments are divided into three different classifications:

(1) The physical changes which take place when a lubricating oil is mixed with various quantities of fuel
(2) The effect of these changes upon the performance of an engine
(3) The rate at which these changes occur on the road

We find it particularly convenient to plot curves such as Fig. 9, showing the relation between gravity and viscosity for mixtures of fuel with each oil in which we are interested. With such data it is a simple matter to determine accurately the extent to which the viscosity of an oil has fallen, simply by the use of an hydrometer. A point of considerable interest is that such curves made for gasoline or kerosene mixtures are so nearly coincident that they can be considered identical for all practical purposes. On the same sheet we have another curve showing the relation between gravity and the percentage of kerosene, so that a determination of the equivalent kerosene content can also be made by the hydrometer. One would naturally expect that the curve between kerosene content and gravity would be a straight line, but it is slightly curved. These curves are more practical for determining kerosene content than distillation methods,

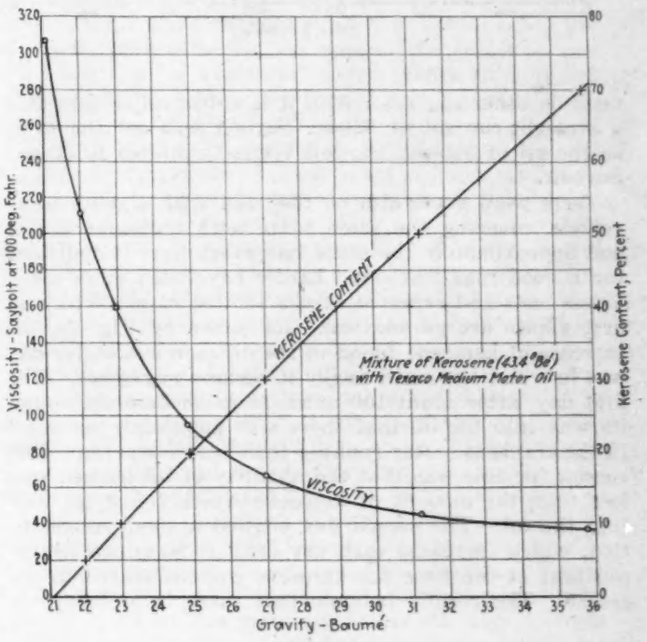
Viscosity - Saybolt at 100 Deg. Fahr.
Kerosene Content, Percent
Gravity - Baumé
KEROSENE CONTENT
VISCOSITY
Mixture of Kerosene (43.4° Bé) with Texaco Medium Motor Oil

FIG. 9

because any separation by a single distillation cannot be complete. A little of the oil goes over with the fuel, while a little of the fuel remains with the oil. It is not at all unusual for the final boiling point of the fuel to be higher than the initial boiling point of the oil.

In order to determine how serious the effect of dilution is upon engine performance, a dynamometer test was made on a model No. 7-R Continental engine which had been run about 300 hours on various tests and was in excellent condition. The oil used was Medium of 300-sec. Saybolt viscosity at 100 deg. fahr., and the various percentages of dilution were made by mixing kerosene with the oil. Strange as it may seem, the power increased and the fuel consumption decreased as more and more kerosene was added, up to about 40 per cent, when the viscosity of the mixture was only 52-sec. Saybolt at 100 deg. fahr. With this mixture the power and fuel consumption were about 5 per cent better, at 2000 and at 800 r.p.m., although the oil pressure had dropped from 15 to 10 lb. One must be cautious, however, about drawing conclusions from this test until the results are compared with

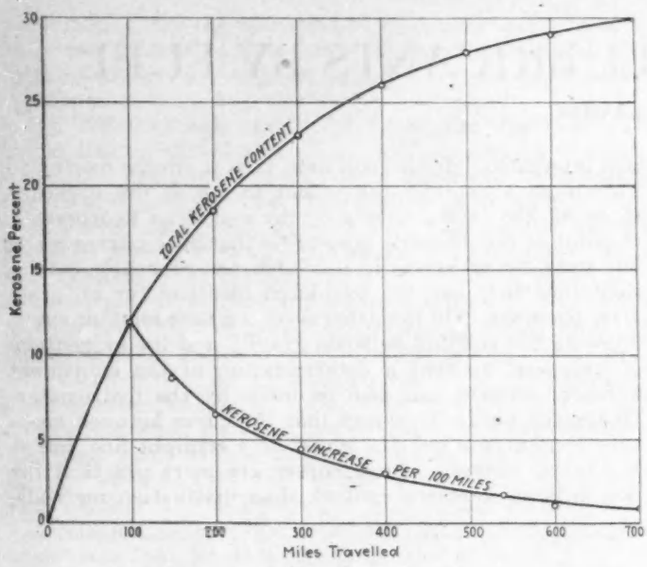

FIG. 10

tests on other engines. Also it is not at all certain that a straight-run oil of 52-sec. Saybolt will act the same as the oil of 300-sec. Saybolt viscosity diluted to 52-sec. Saybolt.

Tests were made also on the road with a commercial vehicle, covering the same route with the same driver and approximately the same load every day. Conditions for a good road test could hardly have been more ideal. These tests and repeated checks showed results which at first glance are paradoxical. As shown by Fig. 10, the increase of kerosene found in the oil each successive day was less and less until finally it became negligible. The first day, after about 100 miles, so much kerosene found its way into the oil that there was apparently more oil in the crankcase after running than before starting. The reason for this was that the quantity of oil burned was less than the amount of kerosene which found its way into the oil. The second day showed a small consumption, which increased each day until it remained nearly constant at the time the kerosene content ceased to increase. The results indicate that there is probably an

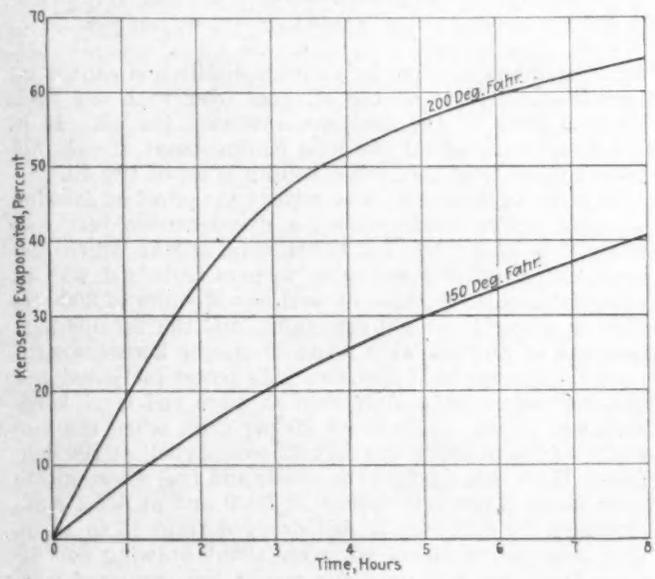

FIG. 11

evaporation phenonemon occurring in the crankcase, the quantity of fuel evaporating increasing with the percentage present in the oil, until the rate of evaporation is equal to the rate of kerosene influx, after which no increase in the kerosene content will occur.

To check this theory of evaporation a carefully regulated stream of air was bubbled through a mixture of 20 per cent kerosene and 80 per cent heavy motor oil, the temperature being held constant at 150 deg. fahr., which represented the maximum temperature of the oil measured during the road tests. The results are shown in Fig. 11, together with a similar test run at 200 deg. fahr. After 8 hours, it will be noted over 40 per cent of the kerosene was evaporated even at this low temperature, which was about 200 deg. fahr. below the initial distilling temperature of the kerosene.

It is clear that the phenomena of oil dilution are not at all what they are usually assumed to be and further experimentation is much needed, to determine not only the effects of dilution but also the laws covering the rate of influx of fuel into the oil and their relation to features of design.

D. G. ROOS:—I can bear out the statements in regard to the amount of dilution of the crankcase oil reaching a constant value. We have been making a series of experiments, operating trucks on kerosene, and we found that the same phenomenon occurred. We also found that plenty of breather capacity seemed to help it. It has also been domonstrated that an oil-pan which is exposed in cold weather to ice-cold air flowing under the car has a tendency to make matters worse, and if a protecting pan is put under it, so that it can be kept warm, the conditions are better.

J. H. HUNT:—I have carried out a good many experiments along the same general line. Some of the data of these experiments have already been published in the September, 1919, issue of THE JOURNAL. I am convinced that the problem will be completely solved when we start with the engine sufficiently heated, in conjunction with a properly-heated distribution system, so that we can start the engine and operate it after starting with normal adjustment of the carbureter. After considering all of the devices which have been proposed for taking care of crankcase dilution, I think that the problem is better handled with something to take care of the starting and initial running, thus preventing the dilution from occurring, than by adding a device of the type under discussion. Some experiments have shown that the situation can be handled in the way that Mr. Kramer has suggested. The best results, in my opinion, will be obtained by less equipment, by putting on some device which will enable us to start without any choking whatever and then operate smoothly right from the start, regardless of the temperature of the engine. The above statements apply to the fuels now used in automobile engines. With fuels as heavy as kerosene, conditions might be different.

H. W. SLAUSON:—The problem of oil dilution is a serious one, especially as it affects the ordinary user. He is warned by the manufacturer to drain the crankcase every 500, 800 or 1000 miles. Very few of us do it. The cost involved is not great, but each car owner feels that the 3 to 4 quarts and sometimes 5 to 6 quarts of oil that he is directed to throw away ought to be perfectly good. Until we can operate our cars so that there will not be this crankcase dilution, is there a possibility of reclaiming this oil commercially?

H. C. GIBSON:—Mr. Kramer has painstakingly shown us which features of the dilution difficulty are of real importance. It is regrettable that we cannot yet know

the final determination resulting from the use of the various projected apparatus referred to. Spontaneous decomposition of the oil film on cylinder walls and of pools on pistons is expected because of the temperature and pressure of combustion, but in ordinary methods to crack oil in appreciable quantity requires exposure for considerable time, far longer than the time of two strokes of a piston. The results of a test where the actual occurrences of normal operation of an engine are reproduced will be most instructive, if only to eliminate a disturbing thought from our minds. I do think that immediate relief in preventing oil dilution is not unattainable, or solely dependent upon the development of new engines. Almost all engines now in use can be satisfactorily fitted with means for evaporating the fuel prior to entry to the cylinder. It is done; in fact, in some tests where the fuel was kerosene, the oil viscosity increased consistently just as in the case of the aviation engine referred to in the paper. Even if fuel-mixture heating devices prevent dilution when they are hot and performing their work properly, there will always be some dilution resulting from starting operations in the less-expensive cars. Any dilution is undesirable and the well conceived and well-worked-out devices described in the appendix to Mr. Kramer's paper will be a boon to the industry and, when allied with properly-designed mixture heaters, form a combination well able to solve the difficulties of dilution.

PROF. O. C. BERRY:—The kerosene-burning tractors have had a great deal of trouble with lubrication, due to kerosene diluting the lubricating oil. In this connection a series of tests conducted by the Purdue Engineering Experiment Station will be of interest. These tests showed that the surface of a steel plate had to be held at a temperature of about 625 deg. fahr. in order to be most effective in vaporizing kerosene, and that the rate of vaporization decreased very rapidly as the temperature was lowered. If the rate of vaporization at 625 deg. fahr. be represented by 100 per cent, then at 500 deg. fahr. it will be about 20 per cent, and at 450 deg. fahr. about 6 per cent.

To show the bearing of this information upon the design of the hot-spot intake manifold, an engine was operated with all of the intake air impinging on one side of a steel plate and all of the exhaust gases on the other. The speed and load of the engine were changed from maximum to minimum conditions, but the temperature of the plate remained nearly constant at about 325 deg. fahr. I am convinced that the temperature is too low in the metal in nearly all of the hot-spots now used for carbureting kerosene.

To my mind the most satisfactory design for a hot spot is the one that will allow the liquid portions of the fuel to come in contact with the manifold, but will keep most of the air away from it. This will prevent the mixture from becoming so hot and the metal in the hot-spot will not be cooled down so much that it will take on more nearly the temperature of the exhaust gases. The latter will vary from about 500 to 1200 or 1400 deg. fahr., but will never be hot enough to ignite the gases in the intake manifold.

R. W. A. BREWER:—The remarks of Professor Berry relative to means of preventing fuel from mixing with lubricating oil are liable to lead one astray because he has evidently in mind a matter of normal impingement of vapor on one side of a flat plate and heated gases on the other side of a flat plate. There are many other ways of bringing these two influences together. Lines of work that are being followed do not employ this system of impingement at all; so that the arguments of Professor Berry do not hold. It is possible by keeping the air insulated from the heated walls to treat only the liquid particles; to treat them not by normal impingement but by other means which are effective in preventing the liquid from entering into the crankcase.

A MEMBER:—How does Professor Berry arrive at the figure he mentioned for the vaporization of kerosene?

PROFESSOR BERRY:—The tests were carried out in this way: A steel plate ½ x 4 x 10 in. was placed over an electric heating element and so arranged that its temperature could be controlled accurately. A depression was milled in the top of the plate to receive the fuel and holes were drilled in the plate close to the depression, to measure the temperature of the metal in contact with the fuel. The fuel was siphoned out of a small glass beaker on one pan of a set of chemist's balances, and allowed to flow into the fuel well on the hot plate. The rate of flow was adjusted until the amount of fuel left in the well remained constant. The time required to vaporize a known weight of the fuel was then recorded, together with the corresponding temperature of the steel plate. Since the wetted area in the fuel-well was known, the rate of vaporization per square inch of hot surface could be determined for the various metal temperatures.

MR. MACCOULL:—In regard to the end-point and the evaporation of kerosene, I think there is much confusion between evaporation and boiling. Kerosene, if it is heated in the presence of air or any other gas, can be evaporated at a lower temperature than that at which it will boil. That is what I had in mind in my previous discussion, when I referred to an experiment where a large percentage of kerosene was *evaporated* at a temperature about 200 deg. fahr. below its boiling point.

SYDNEY BEVIN:—I believe that this paper is an excellent start along proper lines, but that it has not gone far enough. Anyone familiar with lubricating oils and gasoline will realize that dilution curves of lubricating oils with gasoline and kerosene can be drawn fairly accurately without experiment with the actual mixtures to determine their viscosities. Knowing the viscosities of the oils under test and the fuels under test, it is possible without any experiment whatever to demonstrate that "a higher percentage of dilution would be permitted with the lighter oil." The conclusions reached seem to indicate that gasoline evaporates from crankcase lubricants as fast as it reaches them, in an engine equipped with a proper breather. My belief is that the problem is one of eliminating the kerosene or equally heavy fuel from the crankcase oil, as that portion of the gasoline which finds its way past the pistons is the heaviest fraction of the fuel. The other fractions will have split off to burn in the cylinder. It would seem that a device for the continuous restoration of lubricating oils would have to be constructed with much care and with an eye to the filtering-out of the oil entering this restoring device and the precipitation of free carbon from the lubricant. I think that it would be simpler to have apparatus installed in every garage to rectify the engine oil, drawing it off periodically.

G. A. KRAMER:—It should be understood that when evaporation is mentioned in the paper, evaporation is meant and not boiling; it is like some wet substance drying in air which does not require heating to the boiling point of water when exposed to an air current; it will dry at much lower temperatures.

As to the possibility of recovering used oils, if by recovery of used oils is meant only the expelling of the

fuel present in it, that is very simple and can be performed by any distilling process. A small still could probably be used. By raising the temperature of the oil to a high enough degree to evaporate the largest proportion of kerosene, which would be somewhere near 550 to 600 deg. fahr., the oil could be recovered. If it is a question of recovering oils which are deteriorated in other ways, that requires more complicated apparatus which probably would be too costly and not easy to install in every garage.

THE VELOCITY OF FLAME PROPAGATION IN ENGINE CYLINDERS

BY DONALD MACKENZIE AND R. K. HONAMAN

FLAME propagation has received much attention, but few results directly applicable to operating conditions have been obtained. The paper describes a method devised for measuring the rate of flame propagation in gaseous mixtures and some experiments made to coordinate the phenomena with the important factors entering into engine operation; it depends upon the fact that bodies at a high temperature ionize the space about them, the bodies being either inert substances or burning gases. Experiments were made which showed that across a spark-gap in an atmosphere of compressed gas, as in an engine cylinder, a potential difference can be maintained which is just below the breakdown potential in the compressed gas before ignition but which is sufficient to arc the gap after ignition has taken place and the flame has supplied ionization. These experiments and the recording of the results photographically are described. The spark chronograph, an instrument designed to replace the oscillograph used in these experiments, is also described and its advantages stated. The results so far obtained prove the fundamental idea that a voltage sufficient to arc a gap ionized by the ignition flame is not large enough to break down the compressed gas. A study of turbulence and knocking, using this method, concludes the paper. [Printed in the February issue of THE JOURNAL.]

THE DISCUSSION

DR. H. C. DICKINSON:—Professor Harold B. Dixon of England is one of a number of able scientists who have made a very extended study of the propagation of explosions in gas mixtures. I had the privilege of visiting his laboratory recently and spending a very profitable day discussing with him some of his past and present researches into this subject. The general problem which has led to most of the researches on gas explosions has been prevention of explosions in mines and in industries where accidental explosive mixtures may occur. The applicability of the results to gas-engine problems is rather accidental.

In 1893 Professor Dixon published a paper in the Philosophical Transactions of the Royal Society of London covering a research on explosions of various gas mixtures confined in long pipes of small diameter, in which he had repeated and verified the experiments of many previous observers and added much new information on the detonation velocities of explosion waves. It appears that in general an explosion wave starts out with a low velocity which increases gradually to a definite limit, after which it is constant no matter what the distance. This final constant velocity only was considered in the paper just mentioned, and in 1903 Professor Dixon published in the same journal a second very interesting paper, continuing this research and including also a study of the initial stages of explosions in glass tubes. Some of the results, to my mind, throw important light on the phenomena of fuel knock, as will be discussed later.

Professor Dixon's laboratory is typical of all the laboratories I visited in England, in that no time or money is wasted on elaborate instruments or equipment. This is in marked contrast to laboratory practice in this country and not to the credit of American methods. For the several important problems now in progress there is not a single piece of experimental equipment which could not be improvised in a few days at very little expense, and yet one will hardly find more accurate and careful work in progress anywhere. One experiment is intended to find the normal ignition temperature of mixtures of pentane, alcohol, ether, etc., with air. This measurement has commonly been made by flowing the mixture past a hot wire or by some such device. This is recognized as open to very grave question. The results may be hundreds of degrees in error, mainly due to catalytic action of the heated metal. Professor Dixon has devised a simple method which seems to avoid the error. The combustible gas and the air are heated independently in separate tubes and allowed to flow together when hot, and the temperature at which the gas takes fire is noted. There are, of course, some questions of accuracy involved here, but they are less serious than with other methods. Another problem is to determine the compression ratio at which such mixtures as the above will fire spontaneously under adiabatic compression. For this purpose the professor uses a tight-fitting piston in a long cylinder with a small pile-driver to produce the compression and a positive stop to limit the motion of the piston. He is studying the behavior of various substances and mixture ratios in this way. For the measurement of detonation velocities, which is being applied to a large number of gas mixtures not previously studied, there is a 100-meter pipe, 1 in. in diameter, coiled up in a wash-tub of water. A thin strip of silver foil is blown out by the explosion wave near the firing end of the tube and another near the far end of the tube; each breaks an electric circuit, causing a spark, and the interval between these is the time required to travel about 100 yd., this requiring somewhere between 0.1 and 0.01 sec. This is only a part of the important work in progress at Professor Dixon's laboratory.

As for the bearing of Professor Dixon's results and others of a similar nature on fuel knock in engine cylinders, I believe a careful analysis of these results offers a very interesting if not conclusive explanation of the mechanics of this effect. When an explosion wave is started it travels slowly, as we have shown by measurements, but it ultimately reaches a very high velocity, this velocity being sometimes 10,000 ft. per sec. The final velocity is practically independent of pressure, so that it would be about the same in a cylinder at 5 atmospheres

as in a pipe at 1 atmosphere pressure. While the distance which the explosion wave travels before reaching its maximum speed in most of Professor Dixon's experiments is much too great to occur in an engine cylinder, this distance is very sensitive to changes of pressure and quality of mixture. A calculation from his results shows that at cylinder pressure, with gas mixtures likely to occur, it is quite possible for these detonations or maximum velocities to occur within the engine cylinders.

If such is the case, let us consider what may happen. In the first place, the mass of the charge never burns simultaneously, but in a progressive wave the speed of which is, however, enormously great. This wave always spreads out from the ignition point with a smooth wave-front something as a wave on the surface of the water, except in three dimensions. The instantaneous pressure at the front of the wave may be as much as 100 atmospheres when the initial pressure is 1 atmosphere, and the formula for the maximum pressure shows it to be proportioned to the initial pressure; thus, in a cylinder it might reach several thousand pounds per square inch. This pressure, however, lasts only for about 1/10,000 of a second, as shown by Professor Dixon's photographs, and it is not a true pressure in the usual sense, because it is due to the impact of a wave of gas molecules traveling at an enormously high speed but with very little weight or pressure behind it. When such a wave-front meets the wall of a cylinder it is like a shotgun charge of very fine shot striking almost simultaneously and would be expected to produce the sort of sound which we know to result.

Now if the position of the ignition point is such that the detonation wave-front reaches some part of the cylinder wall like a wave striking shore in an exact on-shore wind the effect will be greatest. If the wave strikes diagonally due to change in spark-plug position or cylinder shape, the effect may be less. Finally, the impact of such a wave would produce an amount of sound all out of proportion to the mechanical effects, since the inertia of the gas, due to its very small weight, is too small to impart any great mechanical action to the engine parts. For this reason the actual instantaneous pressure can probably not be measured with any approach to accuracy. If applied to a piston even of the lightest weight, the inertia is many times too great to permit any accurate measurement. If applied to a light diaphragm, still the inertia is too great; also such a diaphragm requires a support which would further interfere with measurements. Some other methods might be better for the purpose. One of these was applied by Professor Dixon. If a high-speed wave of this sort strikes a glass wall and the glass wall is broken, it is almost certain that the instantaneous pressure was at least as great as would be the steady pressure necessary to break the glass. We know of only one other method which might be superior to this for the purpose.

PROF. C. A. NORMAN:—This paper is a valuable first step in an investigation of flame propagation and combustion phenonema in a high-speed internal-combustion engine under actual working conditions.

The maximum speed of flame propagation noted was 41.27 ft. per sec., applicable to comparatively long distances of travel; the minimum speed was 21.13 ft. per sec., applicable to short distances. The engine ran at 1400 r.p.m. A half stroke consumed 0.021 sec. The maximum distance traveled by the flame in this time would be about 11 in. In other words, the combustion would have time to spread throughout the whole charge during the time occupied by the working stroke, even in engines somewhat larger than the Liberty. Assume, on the other hand, that, during the comparatively slow travel of the piston near dead-center, we could consider the combustion space as retaining practically constant volume for as much as one-eighth of a revolution, in this case about 0.005 sec. With application of the minimum speed of propagation in this more limited space, the distance of travel in the interval considered would be from 1.3 to 1.5 in. It is thus evident that the flame would not spread through the whole combustion space in the time mentioned and that combustion would not take place at constant volume. Even with the comparatively rich mixture and the high-grade gasoline used, combustion would in all likelihood continue during almost the whole stroke, with a resultant unfavorable effect on fuel consumption.

Investigations of the character here carried out, but in connection with indicator diagrams showing the pressure conditions in the engine, would be of the very greatest interest for further understanding of the combustion process and its conversion into power.

In conjunction with B. Stockfleth of the International Harvester Co., I have found best fuel economy for a 4 by 6-in. engine between 400 and 600 r.p.m., even though the mean effective pressure and the power were well sustained at much higher speeds; this, using ordinary gasoline. A fractional distillation test of the fuel used would be a valuable addition to the data furnished in the paper.

SUPERCHARGERS AND SUPERCHARGING ENGINES

BY MAJOR G. E. A. HALLETT, U. S. A.

IF at great altitudes air is supplied to the carbureter of an engine at sea-level pressure, the power developed becomes approximately the same as when the engine is running at sea level. The low atmospheric pressure and density at great altitudes offer greatly reduced resistance to high airplane speeds; hence the same power that will drive a plane at a given speed at sea level will drive it much faster at great altitudes and with approximately the same consumption of fuel per horsepower-hour. Supercharging means forcing in a charge of greater volume than that normally drawn into the cylinders by the suction of the pistons. Superchargers usually take the form of a mechanical blower or pump and the various forms of supercharger are mentioned and commented upon. Questions regarding the best location for the carbureter in supercharged engines are then considered. Supercharging engines, in which compression in the crankcase or in the lower end of the cylinders is used to force an additional volume of air or mixture into the cylinders after completion of their normal suction stroke, are then reviewed, with discussion of their special features and comments upon present practice. In conclusion, the future of the supercharger is considered and the chief obstacles which must be overcome are mentioned. [Printed in the November, 1919, issue of THE JOURNAL.]

THE DISCUSSION

T. S. KEMBLE:—Major Hallett's paper should be of greater than passing interest, especially to those who

have had any part in aeronautic development. The opening sentence of the paper tends to convey an impression which was perhaps not intended. I mean the impression that the powerplants of commercial airplanes will be called upon to deliver full sea-level power habitually at very great altitudes. I would not assent to any assertion that data are lacking for the design of light engines capable of delivering high sea-level power for long periods. Another factor however militates strongly against the habitual use of full sea-level power. Our present-day airplanes have maximum power equipment sufficient to fly at speeds too high for greatest fuel-per-mile economy. This is necessary and desirable in order that partial decrease of power from any cause may not involve a too serious risk. When the airplane is brought to a proper commercial basis it will continue to carry excess power, but will fly at a speed approaching that which is most efficient. It will use maximum power only in climbing and in emergencies. It is fortunate that this condition obtains. It means that however sturdy the airplane engine becomes, the conditions of service will give longer life and require less attention than would be possible otherwise.

We have a further advantage in that superchargers will ordinarily be called upon to make up only part of the difference between sea-level and great-altitude air density and cooling, and propeller problems are rendered less difficult. An added advantage in connection with superchargers lies in the simple means which they offer for furnishing the pilot and passengers with air at such temperature and density as to obviate the discomfort ordinarily attendant upon great-altitude flying.

MAJOR G. E. A. HALLETT:—Mr. Kemble's points are good. I heartily agree with him as to the necessity for running airplane engines at far below their maximum power output for the sake of durability, especially for commercial use. A supercharged engine, supercharging to bring it up to 0.8 of its sea-level power at an altitude of 20,000 ft., would correspond in durability to an unsupercharged engine running at 0.8 of its rated sea-level power, or approximately wide-open throttle, at 5000 ft. but would make much greater speed due to the lowered density of the air at the great altitude.

As to the need for full speed in commercial aviation, there are times when this is the most economical speed. For example, consider the extreme case of an airplane capable of making 100 m.p.h. flying while throttled down to an air speed of 70 m.p.h. and flying against a 70-mile head wind. The result would be that the airplane would be standing still and the fuel necessary to drive it at an air speed of 70 m.p.h. is totally wasted as far as getting anywhere is concerned, while if the throttle is opened so that the airplane makes its maximum air speed of 100 m.p.h., the fuel that is burned is driving the airplane toward its destination at the rate of 30 m.p.h. Hence, a greater economy is effected than if the engine is run partly throttled down and, as Mr. Kemble points out, a supercharger, supercharging to only 0.8 of sea-level power at 20,000 ft., for example, is much easier to accomplish and presents much less of a propeller problem than complete restoration of power at this or greater altitudes.

Mr. Kemble is entirely correct in his statement that the supercharger provides means of keeping the pilots and passengers comfortable with air of the proper temperature and density. The Engineering Division has for some time planned to arrange an airplane in this manner for Major Schroeder's use in his extreme great-altitude experiments and for use in proposed high-speed cross-country flights at considerable altitude.

BETTERING THE EFFICIENCY OF EXISTING ENGINES

BY H. C. GIBSON

FIRST reviewing the history of the progressive insufficiency of the supply of highly volatile internal-combustion engine fuels and the early efforts made to overcome this by applying heat to produce rapid vaporization, the author gives an outline of the methods already found valuable in offsetting the rising boiling points of engine fuels and states the resulting three-fold problem now confronting the automotive industry.

The tendency to subordinate efficient vaporization to the attainment of maximum volumetric efficiency is criticised at some length and the volatility of fuel is discussed in detail, with reference to characteristic distillation, time of evaporation and distillation-temperature curves which are analyzed.

Heating devices are then divided into four classes and described, consideration then being given to fuel losses outside the engine. The use of some pressure-indicating apparatus such as a manograph, for determining pressure conditions within the cylinder, is believed necessary.

Summarizing, ten definite recommendations are made for bettering engine efficiency. [Printed in the January issue of THE JOURNAL.]

THE DISCUSSION

F. C. MOCK:—Discussions of intake-manifold design can only be profitable when they speak in definite terms of conditions that actually exist. Just now each engineer has his own idea of what constitutes a successful design, and yet all the different designs we have been able to test have given best results, for a standard grade of fuel, when brought to practically identical mixture and temperature conditions.

One designer advocates "no heat," but concedes that his car operates best on a fine summer day; another advocates "a lot of heat" and points to his flexible and economical operation in cold weather, but does not say much about pulling through sand in August. But when we put a pyrometer in the intake manifolds of these respective cars, we find that at the time of their admittedly best performance, on the same fuel, they will have come to practically the same mixture temperatures, probably within 20 deg. fahr. It all narrows down to the grade of fuel, the mixture temperature and, to some extent, the method of heat application. What we should do is to decide upon the grade of fuel we must prepare to use, find experimentally what temperature conditions will give proper operation with this fuel, and then design the car so that these mixture conditions can be maintained under the year-around, country-wide service American cars must give.

C. F. KETTERING:—I do not believe that the knock is in most cases the result of incomplete vaporization, as Mr. Gibson stated. Our indicator showed here today that the knock may or may not be due to that. There

are certain conditions under which, apparently, the lack of vaporization is the cause.

We put ether in that engine today to demonstrate what we thought about it, and the indicator answered back what we thought about it. I agree that whenever we find a dozen and one remedies and half a dozen panaceas, there is just one answer, and that is that no one knows anything about it. In these discussions we are all hitting at this thing from different angles; I know that a year hence, when we return here and discuss this matter, we will have some real facts.

Mr. Gibson says that we ought to force each manufacturer to put something on his car to give better fuel economy. That is perfectly fine, but you must understand that these cars run all the way from Florida to the North Pole, under all sorts of varying conditions, and we have not yet struck the mean average where we can do something and do it constructively. Mr. Gibson is doing a good work by taking the specific problems and fitting them to the conditions here. We must begin to do many things; finally, the general solution will come and it will be applicable. When it does, it will be so simple that we will wonder at our former anxiety.

THOMAS MIDGLEY, JR.:—With regard to the relation of volatility to knock and the resultant discussion, I have some indicator cards here and will show you some results. Regarding this subject, we find that when we look back over the records we obtained, we have some peculiar confirmation which is at the same time closely associated with this problem of volatility. I have here a card made with ether, which caused knock during the demonstration. It is a very volatile fuel and if this propagation wave is set up in it, we get typical cards when running on ether that have just one kick, a very high kick that makes much noise, but there is only one of them. As we run other fuels that will give the same knocking property, as in the case of the kerosene running up in volatility, we can imagine that the wave of detonation passes through the mixture, which has not been properly volatilized for combustion, and find that a card from kerosene has a lower initial kick than ether, but that it records two kicks on the indicator. This shows that we have a first wave passing through and then, as Dr. Dickinson suggested, another wave coming back. Passing on up the scale of volatility to fuel oil, which is still less volatile than kerosene, the indicator shows a still lower initial kick than the kerosene, but it shows the presence of three succeeding kicks. I think that is a fairly good representation of the relationship of volatility to knocking; it is not the primary cause of the knocking, but it enters in by increasing the number of these little kicks, all of which come so closely together that they sound as if they were simply one knock.

A. M. WOLF:—Mr. Gibson and Mr. Vincent have brought out the variations in exhaust heat due to variable load and speed. It will be seen that this heat is furthermore dependable upon carburetion, ignition, etc. By "carburetion" is meant the entire process, starting with the carbureter, until the mixture is fired. This includes distribution through the intake pipe, valve-timing, and gas flow past the valves and into the cylinder. Various locations of the spark-plug, and the shape of the combustion chamber, water-jacketing and valve-timing, all influence the temperature of the exhaust gases. They are at the extreme end of the numerous processes that occur, and any variation in any one will affect the heat. Due to the wide variation, it is necessary to closely control the heat.

I agree with Mr. Gibson that the fuel should not be heated to a point where trouble due to evaporation may take place. I do believe, however, that whether the fuel is heated to some extent or not, its temperature should be maintained within a very close range. Controlling the heat of the in-going air does not seem to me to be sufficient. The temperature of the carbureter body and the fuel within it should be closely controlled. If we design a carbureter to handle a particular fuel, the jet sizes are proportioned accordingly, assuming a fixed viscosity of the fuel. A wide variation in the temperature of the fuel will nullify all our calculations and the flow through the jets will change. If the fuel cools, the viscosity will naturally become greater and the flow through the jets will be diminished, due to the added internal friction of the fuel. This, of course, applies to the lower grades of fuel, which, as we go down the scale, show a greater change of viscosity for a given change of temperature. In making measurements with various scientific instruments, we always define the temperature at which the measurements were made, and in a great many instances this temperature is standardized. With this same form of reasoning in mind, we must maintain the temperature of the fuel in the carbureter within a fairly close range of temperature, to get suitable operation of the engine regardless of outside temperature changes. The carbureter is a metering device, as is the Saybolt viscosimeter. Temperature is as important in a carbureter as in the latter device. While fuel-injection engines are usually of the slow-speed type, the same thought applies, due to the variations which would occur with changing viscosity when the fuel passes through the pump and spray elements. As such engines become more flexible, the greater will be the need for temperature control of the fuel. It will be interesting to note the actual change in viscosity as indicated on the Saybolt universal instrument. These figures were obtained from Texaco water-white kerosene of 43.5 deg. Beaumé.

Temperature, deg. fahr.	0	32	50	70	100
Viscosity, sec.	47	38.8	36.7	35.2	33.6

While I do not know of tests having been made to determine the restriction to flow through the jet which will occur, due to the metallic contraction of the jet nozzle as the temperature lowers, the above figures give an actual idea of temperature-viscosity effect on an orifice.

As stated before, the subject of carburetion covers the period from the time the fuel enters the carbureter until it is exploded within the cylinder. It is even hard to confine carburetion within these limits, because we can consider the removal of the burned gases as having their influence upon carburetion. While the exhaust gases form a distinct subject, they nevertheless overlap carburetion to some extent and it is necessary, therefore, to consider the successful engine as being one in which the many operations that occur within it overlap without interference, and the process of cooperation is as vital as in anything else.

We have heretofore considered the subject of carburetion too much apart from the engine itself, and means for bettering the efficiency of existing engines lie, to a large extent, within the engine itself. Mr. Trego's paper consisted chiefly of the subject of carburetion, and the title of his paper is significant in that he does not call it Carburetion but Needs in Engine Design. It was brought out that there are varying depressions in the different branches of the intake pipe, and herein lie means for bettering efficiency. The intake pipe should insure constant velocity of the mixture, and it should be of uniform section. It should also be free from sharp bends which, by centrifugal force, throw the

globules out of the center of the mixture stream. The I-head engine has in its favor the fact that there are two less changes in direction in the flow of the mixture into the cylinder than would occur in the same distribution system of an L- or a T-head engine. When the mixture passes by the valve head, it enters directly into the cylinder in the I-head engine. In the L- or the T-head, after the gas has flowed past the valve, it changes its direction usually 90 deg., and then another 90 deg. into the cylinder. A great many L-head engines require seven changes in direction for the mixture after it leaves the carbureter; others have six. In the I-head engine we usually find four or five changes of direction and it is possible in this type of engine to reduce the number to three. This is one factor in favor of the I-head engine. It is an interesting fact that on some engines of the L-head type not only are there seven changes in direction of flow which ordinarily can be made of small resistance due to easy curves, but that some manifolds require an absolute reversal in direction in the flow of the mixture, and sometimes these bends are exceptionally sharp. By "entire reversal of flow" is meant that the mixture travels back in an opposite direction from which it came.

In the L or the T-head engine we have the conventional valve-pocket. "Pocket" is a very good term to describe the deficiency of this combustion-chamber space. In the cross-section of an engine we have usually made the valve-pocket height very small, and the roof is usually level with the roof of the combustion chamber or slightly below. When the valve opens we do not have a full flow past the valve head, such as is assured in ordinary calculations. Due to the poor pocket design, most of the flow is under half of the valve head. This is furthermore accentuated by the closeness of the vertical wall of the pocket to the edge of the valve head, and some engines show such a small distance at this point that the efficiency of the flow around the valve near the vertical wall is very low. In the ordinary L-head engine the vertical wall will usually follow the valve head over a sector of 120 deg., and it is therefore vital that sufficient clearance be allowed at this point. It is necessary that the old pocket be eliminated altogether, and that we forget the old form of combustion chamber. The space over the valve should be the highest portion of the combustion chamber, with the roof over the piston sloping off gradually until, at a point across from the valves, the height is lower than at any other point. It is noted that engines are just beginning to come through with this feature incorporated.

In referring to the angular distance in which the vertical wall of the combustion chamber follows the valve of an L-head engine, the I-head engine offers the advantage that the valve is practically tangent to a large circle representing the diameter of the combustion chamber, and therefore the angular distance offering resistance to flow past the valve is materially less.

Other than the reversal of flow which occurs in an intake pipe, and the various resistances offered in the pipe due to change in direction of the pipe itself, we also have in the multi-cylinder engine having six or more cylinders the fact that one cylinder tends to rob the other when the intake periods overlap. In six-cylinder construction we recognize the overlapping of the exhaust-pipe valves and conduct the gases away in order to avoid "backing up" in one cylinder from the other. It seems that in regular automobile design on such engines we should provide multiple carbureters as is done in racing and aeronautical work.

The water-jacket intake pipe or manifold within the cylinder-block can well be relegated to the past, along with the unjacketed, frosted manifold, for the reasons that Mr. Gibson has brought out. In the application of an external manifold, however, the designer has been less thoughtful of eliminating the sharp bends, and more thought must be given thereto. A statement was made during the discussions that the external manifold is desirable in order that the engine of the future can remain the same by replacing the old external manifold. This, to my mind, seems a temporary expedient only, in that an engine to handle low-grade fuel must be built within itself apart from the intake pipe, to handle it. In other words, we must build the engine around the fuel and not try to adapt the fuel to the engine by means of an intake pipe.

H. C. GIBSON:—I think Mr. Kettering gave the impression that my suggestion was that manufacturers be forced to put such devices on their engines. I did not even hint such a thing. My suggestion was that manufacturers be urged to use indicating apparatus and investigate for themselves. I would not try to force them to do even that.

The consensus of opinion expresssed in the discussion of my paper appears to be that the problem of Bettering the Efficiency of Existing Engines is practically the same as that of Bettering the Efficiency of Future Engines and that it narrows down to the very simple statements that

(1) Evaporation of the fuel is essential
(2) To attain adequate evaporation without partial destruction of the fuel requires maintenance of definite temperature in each contributory process of evaporation
(3) The requisite temperatures must be maintained automatically, indicating the use of thermostats
(4) Although existing engines have limitations due to design, nevertheless their fuel efficiency, life and dependability, can be vastly improved
(5) The application of the necessary principles to the future engine is a simple matter as has been cleverly brought out by Mr. Wolf

GROWTH OF SHIPBUILDING IN THE UNITED STATES

IN April, 1917, there were in the United States about 61 shipyards with 234 ways in which vessels of 3500 deadweight tons could be constructed. In November, 1918, ship construction had been developed to a point which increased the number of shipyards to 223 with 1099 ways. There were launched in 1917 106 ships totaling 708,970 deadweight tons and in 1918 812 ships totaling 4,244,126 deadweight tons. More than 530 of these were delivered as complete, representing tonnage of 3,026,000 deadweight. In 1919 more than 6,000,000 deadweight tons was delivered. The shipyards of this country have launched 2093 ships representing 11,706,836 deadweight tons and actually delivered 1885 of them with a 10,509,457 tonnage of deadweight up to March 30, 1920. There remain of war construction program 426 ships of 3,092,954 deadweight tons.—From an address by Rear-Admiral Benson, chairman of the Shipping Board.

ACTIVITIES OF THE SECTIONS

MOVING pictures taken by the Novograph camera were a novel feature introduced at the meeting of the Metropolitan Section held in New York on April 8 at the Automobile Club of America. A. F. Masury, chief engineer of the International Motor Co., gave a talk on Tire Deflection and Unsprung Weight in Trucks.

The Novograph camera differs from the ordinary moving picture camera in that a greatly increased number of exposures is taken per second. In reproducing the Novograph picture before the audience, the film is slowed down. This has the apparent effect of very materially retarding the motion of the subject photographed, which permits a much closer study of the movement involved than is the case when pictures are taken with an ordinary camera. The pictures shown at this meeting gave an interesting comparison between the results arrived at by mathematical formulas for calculating spring action, and the actual results shown visually. An opportunity was afforded also to study the relative spring deflections with solid and with pneumatic tires as well as the lagging action of the travel of the pay load upward and downward with reference to the spring deflection.

The subject, which was discussed at considerable length by members and guests attending the meeting, was of such interest that it was scheduled for presentation again before the Detroit Section on April 30.

The technical session was preceded by a dinner, a short business session and moving pictures of maneuvers of French tanks. There were about two hundred in attendance.

The Minneapolis Section held another of its series of meetings on different phases of tractor design on April 1. A. F. Moyer of the Toro Motor Co. took up the subject of tractor weight and drawbar pull. The proper design of the tractor to prevent loss of steering control and overturning was the theme of the address.

In discussing weight distribution as a factor in stability, consideration was given to the various kinds of surface and the different degrees of slope on which the machine must work.

Mr. Moyer mentioned the development of a light-weight tractor capable of working at relatively higher speed than those of current practice as a possibility of the near future.

At the Mid-West Section meeting held on April 9, the veteran John Secor, who is 83 years young, consulting engineer of the Advance-Rumley Co., presented a paper on Kerosene as a Tractor Fuel, which was of marked interest and is well worthy of the study of engine designers. Mr. Secor stated that a heavily preponderating majority of the tractors now in use in this country are run on kerosene. He recalled to the attention of the members that Dugald Clerk pointed out as early as 1896 the inefficiency of the oil engine as compared with the gas engine, and that as much as half a million dollars was spent in the early days on types of engine such as the Brayton without attaining commercial success. He said that the first step in the operation of kerosene tractor engines, which were governor controlled, consisted of recognition of the difference in the properties of the various fuels derived from crude petroleum, resulting finally in tractor engine operation with kerosene not inferior to that with gasoline. Mr. Secor expressed the view that all of the controlling factors of compression must be correlated with air density conditions. He defined kerosene as a material having an initial boiling point of 304 deg. and an end-point of 580 deg. fahr., 20 per cent distilling over at 410, 45 per cent at 420 and 90 per cent at 500 deg. fahr.; and gasoline in turn as having an initial boiling point of 100 deg. and an end-point of 428 deg., with corresponding intermediate boiling temperatures of 220, 275 and 365 deg. fahr.

A joint paper on truck maintenance was presented by A. Stockfleth and N. G. Anderson, truck engineers of the International Harvester Co. This paper dealt with truck design as affecting service. The discussion was of a very animated nature. The point was made that factory service of the future should be planned so as to make possible in case of a road breakdown the convenient installation of any parts, even an entire engine. Designs which necessitate the tearing apart of a vehicle to gain access to some part thereof which has failed were severely condemned. Among those taking part in the discussion were engineers engaged in the supervision of the operation of large fleets of trucks, and in providing service for various elements of truck maintenance, such as storage batteries.

PERSONAL NOTES OF THE MEMBERS

James B. Dillard, formerly chief of the engineering division of the Ordnance Department with the rank of colonel, has resigned his commission in the Army and is now a member of the executive staff of the Cleveland Twist Drill Co., Cleveland.

Dwight T. Hersey has resigned as assistant sales manager of the Splitdorf Electrical Co., Newark, N. J., to accept the position of general manager with the Jenkins Vulcan Spring Co., Richmond, Ind. He has been connected with the Splitdorf organization for the past eight years, first as a branch manager and later as Mid-West sales manager with offices at Chicago before becoming assistant sales manager.

Lewis P. Kalb has resigned as assistant supervisor of engineering with the Standard Parts Co., Cleveland, to accept a position with the Kelly-Springfield Motor Truck Co., Springfield, Ohio.

H. H. Keeports, who was formerly assistant general manager of the Anderson Forge & Machine Co., Detroit, is now manager of the crankshaft division of the Canton Drop Forging & Mfg. Co., Canton, Ohio.

C. G. Keller has been appointed chief engineer of the Bessemer Motor Truck Co., Grove City, Pa. He was formerly mechanical engineer with the Robeson Cutlery Co., Perry, N. Y.

William D. Lowe has accepted the position of sales engineer with the Easton Machine Co., South Easton, Mass. He was formerly sales engineer with the Hess-Bright Mfg. Co., Philadelphia, and later was associated with Manning, Maxwell & Moore, Inc., New York City, in its engineering and advertising departments.

Dent Parrett has resigned as president of the Parrett Tractor Co., Chicago, to accept the same position with the recently established Parrett Motor Corporation, also of that city.

Raymond E. Plimpton has joined the forces of the Wales Advertising Co., New York City, where he will devote his time primarily to the handling of advertising campaigns of a technical and semi-technical nature. For a portion of the time this country was at war he was connected with the engineering division of the Motor Transport Corps and later with the George H. Gibson Co., New York City.

J. Howard Rees has resigned as supervisor of the export service department of the Hudson Motor Car Co., Detroit, to accept the position of president and general manager of the C & B Vacuum Street Cleaner Co., Columbus, Ohio.

Charles H. Tavener has severed his connection with the Curtiss Engineering Corporation, Garden City, N. Y., and has engaged in the practice of consulting aeronautical, industrial and production engineering with laboratory facilities at New York City and Boston. During the war he was successively a mathematical designer, production engineer and assistant plant engineer with the Curtiss corporation.

John Younger, vice-president of the Standard Parts Co., Cleveland, has received a citation for exceptionally meritorious and distinguished service as advisory engineer in the designing and production of the standard motor vehicles adopted by the United States.

Marine Heavy-Oil Engine Installation Practice and Development Possibilities

By HUBERT C. VERHEY,[1] *(Non-Member)*

PENNSYLVANIA SECTION PAPER *Illustrated with* DIAGRAMS

THE undisputed economy of the Diesel-type engine using heavy fuel oil is recognized, as no other power-generating unit of today shows better thermal efficiency. It is the result of the direct application of fuel in working cylinders, thereby producing heat to do work in the engines in the most direct way. Trans-

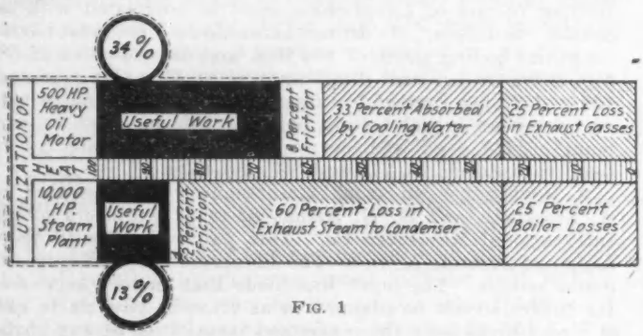

FIG. 1

mission processes, such as the burning of fuel under a boiler to produce a working agent which must be carried to the prime mover, are less economical. The various factors which enter into a comparison between steam and heavy-oil installations are illustrated in Fig. 1.

Heavy-oil engines have been developed, built and successfully operated in ships, while greater progress is in sight since America has given attention to this means of propulsion and our manufacturing companies having previous experience with oil engines are now engaged in production of large-size engines for use on board ships. Licensees of European manufacturers located in this country are in possession of leading shipyards, but none of them has been able to produce heavy-oil engines up to this time, owing to the pressure of war work.

To bring as many individuals as possible in contact with the Diesel-engine situation, for the sake of rapid advancement, I have treated the whole subject in a more or less elementary manner. The diagrams and sketches are intended to explain the working principles of such types of two and four-cycle engines as are now in actual operation in cargo ships throughout the world, these engines being of the single-acting type, notwithstanding that double-acting and opposed-piston-type engines have been built and are now being tried out.

WORKING PROCESSES OF DIFFERENT TYPES

Figs. 2 and 3 illustrate the working process of four-cycle engines. Figs. 4, 5 and 6 are working diagrams of two-cycle engines. In each case the various functions during either the upward or downward strokes are plainly described, the dead centers are marked and the free-hand curves shown illustrate the increase or decrease of pressure during the various periods. The valves or ports necessary for any of the systems are seen in the diagrams showing the different crank positions, in addition to the type of piston used. In each case the rotary diagrams illustrate the various functions in succession, in a direction marked by the arrow and in approximate relation to the respective dead-centers.

In the case of four-cycle engines (Figs. 2 and 3) during the first downward stroke, pure atmospheric air drawn into the cylinders passing by the inlet valves, or air taken from the atmosphere and forced into the working cylinder under moderate pressure, either from the top or the bottom in the case of two-cycle engines (Figs. 4, 5 and 6), is compressed during the upward stroke of the piston to a higher degree than is the usual practice in explosion engines. A temperature of approximately 1300 to 1400 deg. fahr. and a corresponding pressure of about 500 lb. per sq.

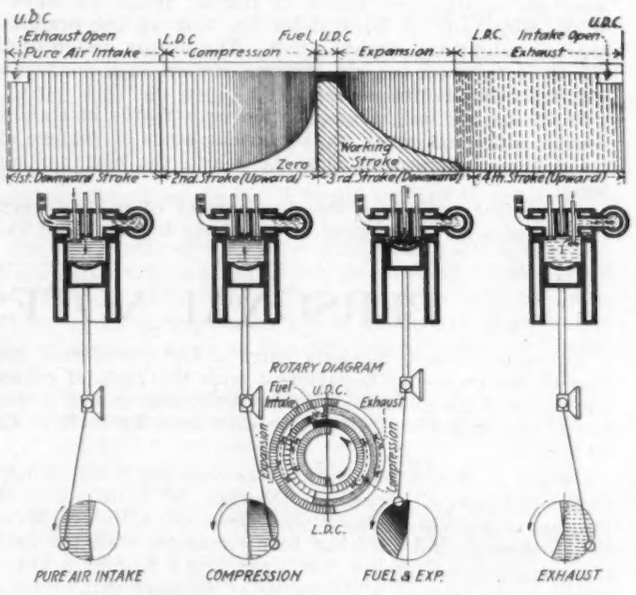

FIG. 2

in. prevails in the working cylinder when the upper dead-center is reached. At this point the fuel oil is sprayed in, under a pressure higher than the compression pressure, and immediately burns very gradually, without appreciable rise in pressure. This is due to the design of the fuel valves, so that the engine works very smoothly and without shocks, because the sudden rise of pressure, such as occurs in gasoline or other gas engines, is eliminated and the peak load is therefore better distributed. Much depends on the timely injection of the fuel oil which is admitted a trifle before the upper dead-center, and the fuel valve remains open during approximately 12 per cent of the downward or working stroke. During this time expansion can take place at any point while the valve is

[1]Formerly head of the Diesel engine unit, Emergency Fleet Corporation, Philadelphia.

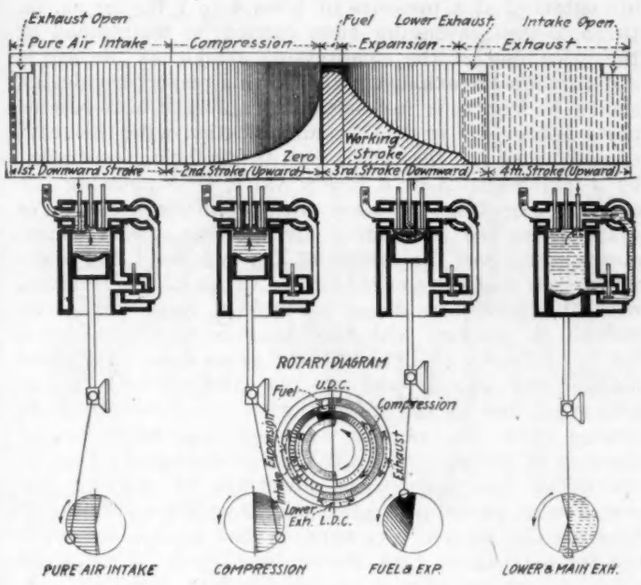

FIG. 3

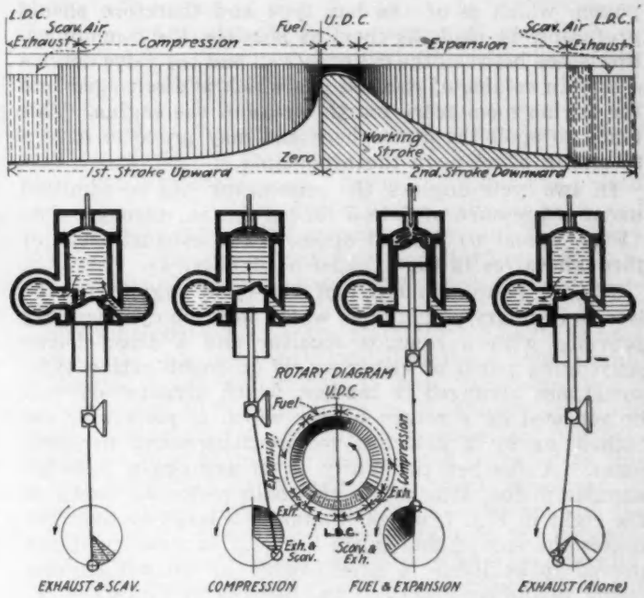

FIG. 5

open, which depends upon the engine load and continues until the exhaust valve in the cylinder-head of four-cycle engines (Fig. 2) opens, or first the auxiliary exhaust valve and then the main exhaust valve opening after that (Fig. 3); and with two-cycle engines until the working piston on its downward stroke uncovers the exhaust ports at the lower end of the cylinder (Figs. 4, 5 and 6). Thereafter, the working process is repeated by the admission of air slightly under atmospheric pressure, which reduction is due to the wire-drawing of the air past the inlet valve in the case of four-cycle engines (Figs. 2 and 3).

With reference to Figs. 2 and 3, the only difference is the application of a so-called auxiliary exhaust valve, arranged for by certain manufacturers to relieve the main exhaust valve from excessive heat. There is no doubt that this arrangement does the work, but the question remains whether additional parts are of sufficient merit to warrant this complication. When the designers take care of the proper velocity of the rushing-by gases, that is to say that when as large a valve as possible is used, trouble can be avoided, although the exhaust valve in any engine is a factor of utmost consideration. Large valves must be water-cooled in addition to their valve cages. The smaller the valve the less troublesome it is, so that two, instead of one exhaust valve, are sometimes used, which adds considerably to the life of such valves but complicates the valve gear. The use of this auxiliary valve necessitates a row of ports at the lower end of the working cylinders and although of less area than the exhaust ports of two-cycle engines, it is questionable whether such a construction is justified or necessary. When applied to four-cycle engines having a partition between the cylinders and the crankcase, an undesirable feature is dominant. Owing to the height of the working

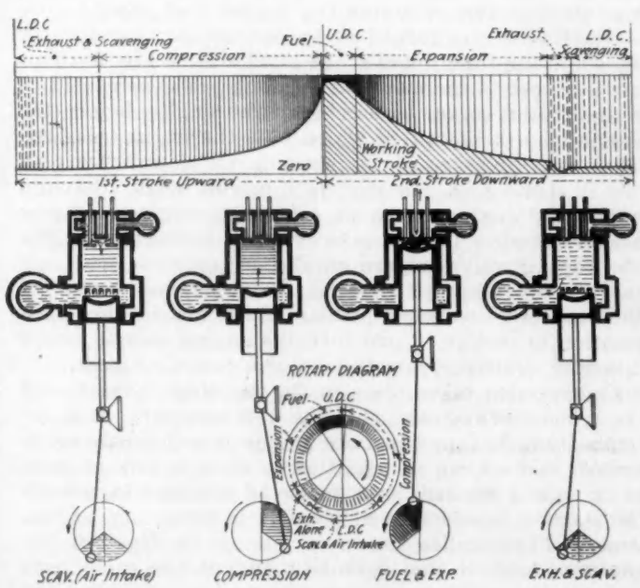

FIG. 4

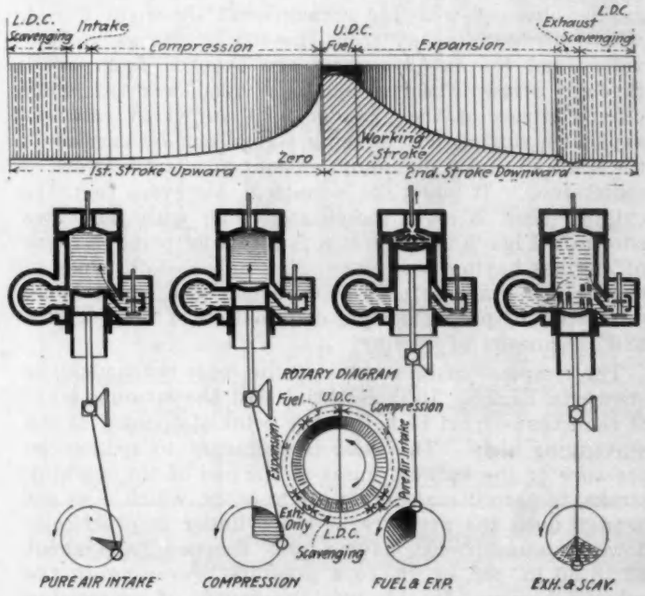

FIG. 6

piston, which is of the box type and therefore should preferably be made as short as possible, the communication space between the cylinder wall and the valve detains a certain volume of exhaust gas which is discharged into the engine room every fourth stroke of the engine. This tends to spoil the atmosphere and may prove to have a sickening effect upon the attendants.

In two-cycle engines the scavenging air is admitted under a pressure of 5 to 7 lb. per sq. in., through slots (Figs. 5 and 6) located opposite the exhaust slots or through valves in the cylinder-head (Fig. 4).

Fig. 7 shows two types of two-cycle engine; on the left an ordinary piston type, where working cylinders are provided with a common receiver and a direct-driven scavenging pump of either single or double-acting type, sometimes arranged in tandem, which arrangement can be replaced by a rotary blower which is preferably detached, or by a detached reciprocating-pump arrangement. A further possibility is to arrange a so-called annular piston, attached to the main piston as shown at the right in Fig. 7, which eliminates a large receiver but makes the engine that much higher. In practice it has proved to be liable to give trouble in vertical engines owing to the possibility of the blowing of foul gases by the working piston, which in that case invites excessive carbon formation by mixing with the lubricating oil of the annular scavenging piston. An advantage of this type of piston is the possibility of starting the engine by admitting starting air on top of the scavenging piston, thus eliminating the extreme cooling down or chill of the walls of the working cylinders, as is the case with the ordinary piston type just discussed, as well as with any other type of engine described in this article. Although there is an apparent advantage in eliminating the starting air from the working cylinders, no trouble has been encountered in well-designed engines, where solutions for the right kind of material to be used are known. Another means of eliminating the starting air from the working cylinders is to arrange the low-pressure stages of the direct-driven air compressor to turn the engine over at sufficient speed to cause combustion of the fuel oil, which is done in certain designs.

Glancing over the constructional features of the two-cycle type as shown, the most efficient scavenging process can be obtained with the arrangement shown in Fig. 4, where air is admitted from the top by means of four valves and the exhaust gases are expelled from below through a row of ports, equally divided over the whole circumference of the cylinder wall, in which case the expansion during the working stroke can be carried to the limit so that a maximum amount of effective work is maintained. It must be admitted, however, that the cylinder-head is more complicated than with the types shown in Figs. 5 and 6, which is a talking point in favor of engines having port scavenging only. Both types of engine are manufactured with equal success, it being a question of proper design, distribution of the material and the means of cooling.

The simplest design, but also the least economical, is shown in Fig. 5. It is essential that the opening point of the exhaust port be before the point of opening of the scavenging slots. This lead is necessary to reduce the pressure of the exhaust gases at the end of the working stroke, to permit scavenging air to enter, which does not happen until the pressure in the cylinder is practically down to atmospheric, having thus dropped from about 40 to 50 lb. per sq. in. to a pressure prevailing in the exhaust header. In this way the benefit of scavenging air entering at a pressure of from 4 to 7 lb. per sq. in. through the scavenging slots cannot be maintained at the beginning of the compressing stroke, as the air is lost through the exhaust port. In this respect the design shown in Fig. 5 is far better, as an additional row of ports is provided in direct communication with the scavenging receiver; the admission of air being controlled by a double-seated or a rotary valve, thus allowing the compression stroke to start with whatever pressure is available in the scavenging air receiver, which consequently improves the output of the cylinder. The additional gear and valve cages located inside of the receiver, with the necessary doors for access, have not given trouble in practice with well-designed engines, except for the difficulty that the exhaust gases enter this space between the cylinder wall and the valve, causing carbon formation due to the mixing with the lubricating oil carried from the cylinder wall and thus necessitating cleaning at times; but this can do no damage as long as the valves are tight. The advantage of starting the compression period at a pressure above atmospheric and equal to the receiver pressure, is also maintained with the top-scavenging type shown in Fig. 4. The valves used are not apt to give trouble, as their functions can be compared with the inlet valves of four-cycle engines, which valves do not invite trouble because their seats are not in direct contact with the exhaust gases.

Workings of the Four-Cycle Engine

I will now describe the working scheme of a four-cycle single-acting marine Diesel engine as shown diagrammatically in Fig. 8, in connection with the arrangement shown in the sketch of a motor ship in Fig. 9, each drawing practically covering the same subject. Fuel oil, which is stored in the double-bottom or ballast tanks of the ship, is pumped to the daily supply tank, going through a manifold and being filtered before entering; it then flows by gravity to the suction chamber of the fuel pump on the engine. As a rule two daily supply tanks are installed, of 12-hr. capacity each, sufficient for both engines in case of a twin-screw installation; this gives the oil a chance to settle. In addition, there is a smaller tank holding a light oil which is used for starting up in extreme cold weather. The oil is strained on its way down before it enters the engine fuel pump.

Starting air is furnished by an auxiliary compressor shown in the foreground at the right side of Fig. 9. This air is stored in the maneuvering tanks as shown in Figs. 8 and 9 and serves to accelerate the engine before the fuel oil can be admitted which puts the engine on duty. The usual pressure of the starting air does not exceed 350 lb. per sq. in. for merchant marine work, although high-speed engines, such as submarine engines, require higher pressure for the sake of quick acceleration. The starting-air valves shown in Fig. 8 serve to admit air into the working cylinders, at the upper dead-center of the respective working pistons which are in the right position to receive it, and turn the engine over in either direction desired, controlled by the reversing gear.

Compression takes place in the working cylinders not receiving starting air, creating the necessary heat for combustion, so that when the engine is sufficiently accelerated, fuel oil can be admitted to all cylinders at once, or in sets if desired, as a device is provided to cut out the starting air as soon as the fuel is turned on, or vice versa. The handles shown in Fig. 8, in front of the engineer, control this operation and at the same time make it impossible to reverse the mechanism unless the

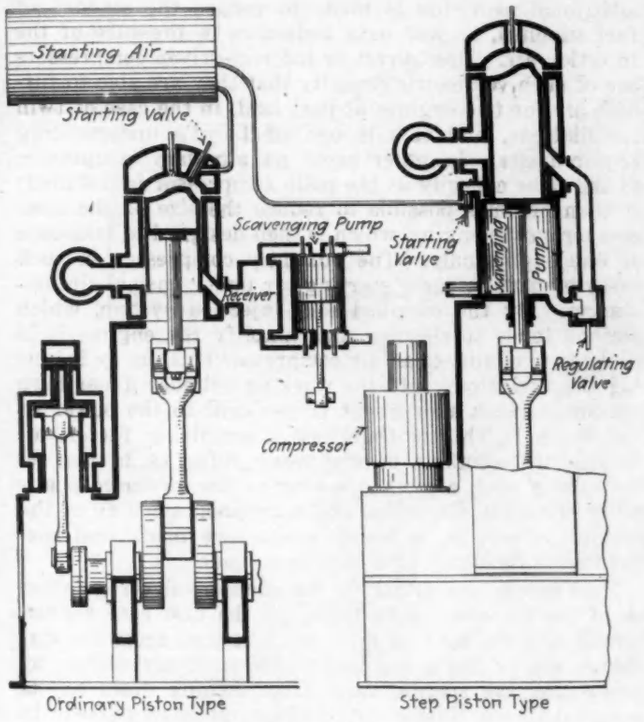

FIG. 7

fuel is cut off. Air from the maneuvering tanks is carried to the working cylinders by means of a distributer, as shown in front of the operator, at the left in Fig. 9, having a conveniently located hand-wheel.

Fuel oil for the working cylinders is supplied by a high-pressure fuel pump driven from the main engine. It is discharged around the fuel needle and forced into the cylinders by means of high-pressure air, the so-called injection air, which is furnished by an air compressor direct-driven by the main engine or detached therefrom and independently driven. Both figures show this compressor in section and elevation respectively. Fig. 8 illustrates the various features. As a rule, for large engines a three-stage compressor is used. Air is drawn in at the low-pressure stage, discharged through a cooler to the intermediate stage, and thence discharged again through another cooler to the high pressure stage; from there it is cooled again on its way to the injection air bottle, which is of sufficient volume to give the air an opportunity to expand and separate the moisture contained therein. Suitable means of draining this bottle at intervals are provided. The pipe-line connection between this bottle and the fuel valve delivers air on top of the fuel oil and blasts the oil into the working cylinders the moment the fuel needle opens. A study of the diagrammatic assembly of valves in the cylinder-heads in Fig. 8 shows this feature.

Pure air for the main working cylinders is taken in by means of a slotted tube closed at the upper end, and passes the inlet valve. Firing takes place after this air is compressed and the exhaust valve expels the gases to the exhaust header and from there to the muffler as illustrated. It will be understood that the walls of the compressor, working cylinder and cylinder heads, and also the exhaust header and the piston, must be cooled. For this purpose a variable-speed pump is installed, drawing water from the sea through a sea-connection as shown in the left corner of Fig. 8, and at the right side of Fig. 9. The discharge can be regulated according to temperature conditions, and sometimes in tropical water an outboard temperature of 85 deg. fahr. must be considered. The cooling water is discharged around the air coolers and in the compressor jacket; from there it is distributed to the working-cylinder jackets and the piston-cooling arrangement. After the water has passed the cylinders, it flows through the cylinder-head and exhaust-valve cage to the exhaust header and from there overboard. The piston cooling-water overflow usually is discharged into the bilges and from there pumped overboard.

The lubricating oil for the main moving parts is as a rule stored in a sump-tank located in the double bottom, in case a forced-feed system is used. I prefer such a system under all circumstances, as it is superior to and more reliable than a gravity-feed system for this particular purpose on marine installations. The oil in this case is supplied by a variable-speed pump, which can be adjusted to suit prevailing conditions, influenced by the amount of oil required and depending upon the temperature of admission of such oil, which affects its viscocity. Enclosing the crankcase allows the re-collection of the lubricating oil in a drip-pan under the crankshaft; thence it is carried to a sump-tank, located low in the ship. The last-named pump draws the oil from there, passing it through an oil cooler if necessary, and discharges it

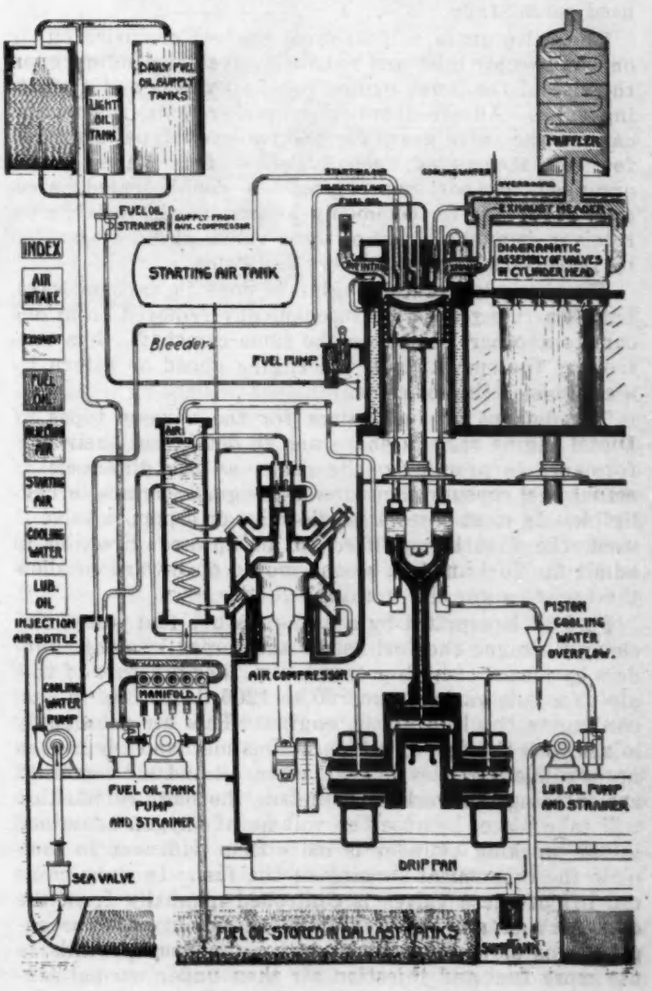

FIG. 8

into a main header running all along the engine and having leads to every main bearing. As a rule the oil enters the upper-bearing cap through a suitable groove which has communication with a vertical and horizontal hole in the journal, a vertical or slanted hole in the crank web, and a horizontal and vertical hole in the crankpin. From there it enters a groove in the connecting-rod brasses, a hole in the connecting-rod proper and is thus distributed to the crosshead and guide. Necessary oil for the journal and crankpin is properly distributed from these grooves.

The top of the crankcase is provided with a stuffing box, through which the piston-rod passes. As a rule, with enclosed engines, there is a space between the cylinders and the top of the crankcase, which in some cases serves for the removal of the piston. This space also allows foul gases, passing by the piston, to escape into the atmosphere, thereby preventing them from mixing with the lubricating oil of the moving parts. In engines of the ordinary marine open type, having no partition between the piston and the crankcase, the foul gases come in contact with the lubricating oil and tend to form an undesirable coating on moving parts and surroundings, and also to pollute the lubricating oil. The working cylinders and cylinder-heads are either separate parts or cast integrally. For large engines, loose cylinder liners and separate cylinder-heads are essential, although a combination of the liner and the cylinder-head has been used successfully.

The valve gears of four-cycle engines comprise either one or two air-inlet and exhaust valves, depending upon the size of the bore; one or two fuel valves and a starting valve. All are operated by rocker-arms, rollers and cams. The valve gears for the two-cycle type, arranged for top scavenging, usually show four valves when arranged for port scavenging. A double-seated valve, or a rotary valve, commonly located in the scavenging receiver, is applied. All of these valves also are operated by rocker-arms, levers, rollers and cams.

The reversing of the engine is done in various ways, but as a rule rollers are mechanically removed from one cam to another located on the same camshaft, thus controlling the operation of the engine ahead or astern by a suitable setting of cams.

The designs of fuel valves for the various types of Diesel engine vary in shape and in detail, but their performance is practically the same, as the difference in actual fuel consumption of well-designed engines is negligible. In most cases a needle-valve or a poppet valve is used, the first being lifted in an upward direction to admit the fuel and the second moved downward to allow the fuel to enter the working cylinder.

Fuel oil is supplied by a high-pressure fuel pump, discharged around the fuel needle and forced into the cylinders by means of high-pressure air. The pressure of this air as a rule varies from 700 to 1200 lb. per sq. in., according to the load of the engine. This air thoroughly mixes with the fuel oil which is thus mechanically broken up into fine particles so that, when oil and air combined are entering the working cylinders, thorough combustion will take place, because the volume of oxygen contained in the working cylinder is more than sufficient to complete the economical burning of the fuel. In some cases the lift of these valves is controlled manually from the engineer's stand. This is of advantage in case the engine runs slow, as at that time a tendency prevails to use more fuel and injection air than under normal conditions at full load, due to the time element. Naturally, additional provision is made to reduce the amount of fuel supplied, as well as a reduction in pressure of the injection air. Most direct or indirect-driven compressors are of such volumetric capacity that they are able to furnish air for two engines at part load, in the case of twin installations, and this is one of Lloyd's underwriting requirements. In other cases an auxiliary compressor of the same capacity as the main compressor is installed; it then becomes possible to reduce the size of the compressor on the engine, which is then designed to take care of one engine only. The auxiliary compressor in such cases is made to serve starting air under normal circumstances. By the so-called solid-injection system, which method tends to cheapen and simplify the engine, it is possible to eliminate an air compressor entirely by injecting the fuel direct into the working cylinder under high pressure, which adds about 10 per cent to the power of the engine. This is therefore a promising factor, although the opinions of engineers differ as to the reliability of such a method, owing to the increased possibility of carbon formation and consequent smoking of the engine in service, although claims are made that mechanical difficulties have been overcome.

Fuel pumps are either of the suction-valve regulation or of the variable-stroke type. In the first case regulation is accomplished by by-passing fuel oil from the discharge side of the pump back to the suction chamber, by preventing the suction valve from coming down on its seat until such time as the surplus oil is by-passed; in the second case by changing the stroke of the fuel-pump plunger, in both cases by mechanical devices regulated by hand.

The average design of a marine heavy-oil engine of large size, say from 750 hp. up, is of the crosshead type and resembles ordinary marine steam-engine practice. The advantages of the open-type marine reciprocating engine have been duplicated, and such practice is followed especially where a gravity-feed lubricating-oil system is used for the main moving parts such as the crankshaft, connecting-rods and crosshead. Builders of marine Diesel engines have shown a tendency to abandon the entirely open type of engines, without sacrificing accessibility, enclosing the crankcase totally with portable doors, which allows the application of a forced-feed lubricating system for the moving parts and materially increases the protection against overheating. In fact, it is my candid opinion that this is the only safe way to proceed.

Modern motorships are equipped with electrically-driven auxiliaries, which include all pumps and the ice machine. Direct current for these motors is furnished by a suitable Diesel-engine-driven generator set as shown at the extreme left of Fig. 8, which as a rule supplies current for the ship's lighting system, a motor-generator being used to reduce the voltage from 220 to 110 volts. Modern motor vessels also have electrically-driven deck machinery such as winches, windlass and steering-gear. The current for this machinery is furnished by additional Diesel-engine-driven generators, of suitable capacity to handle cargo. The use of electric hoisting machinery is not new in our Navy practice, but has been used only to a minor extent on merchant vessels in America. Some European vessels have a complete electric deck-machinery outfit, able to handle cargo at speeds considered sufficient for their requirements, but American practice requires speedier cargo handling, so that the desired horsepower increases, and more space is needed in the engine room for suitable equipment.

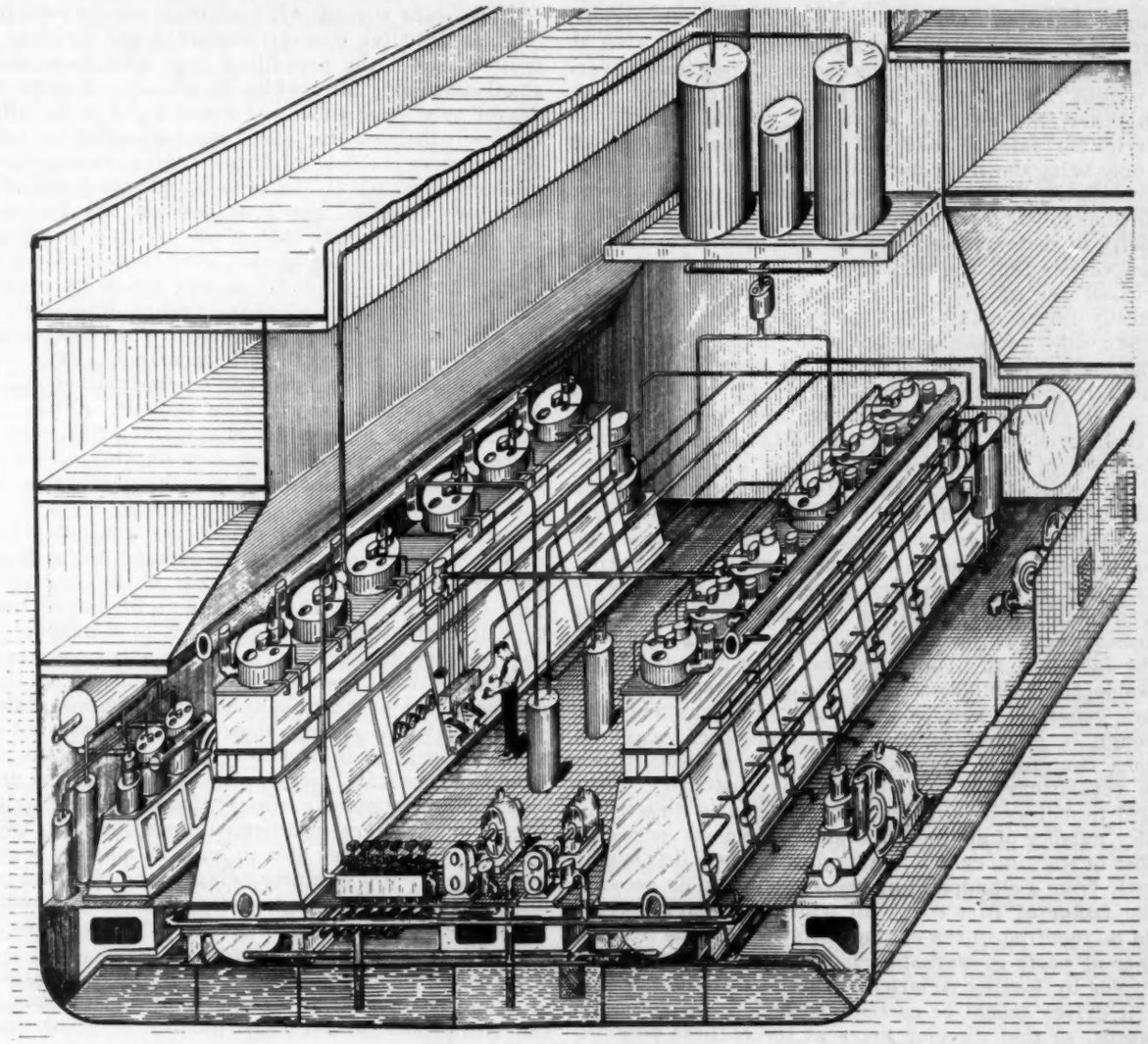

FIG. 9

The heating system throughout the vessel is in some cases operated from a special donkey boiler; in other cases by means of electric heaters receiving current from available Diesel-engine-driven generator sets in the engine room. The latter practice seems the most desirable.

DEVELOPMENT POSSIBILITIES

Regarding development possibilities, it can be frankly stated that United States manufacturers are in as good a position to develop and manufacture heavy-oil engines as European companies that have done the major share in developments as they stand today. From my personal experience, I can say that the duplications of European design manufactured in this country have not suffered the drawbacks of manufacture, such as have been experienced in Europe. This is due in part to the fortunate fact that we have practically started production at a point where the foreigners left off. Moreover, basic materials of high quality, suitable for substitutes for European materials, have been available and applied with great success in many cases. There is no reason to believe that we need much longer depend upon the help of engineers from abroad, as there is talent in office and shop, even though limited, which can be utilized for the education of others, including operating engineers. If possible, steps should be taken by our Government, or by individuals, to prepare to meet future requirements.

Other nations have a sufficient number of men to operate their present motorships because they were the first to adopt this highly economic propulsive power, but they have no surplus. The United States is therefore no worse off in the competitive field than its rivals on the sea. It is for this reason that I make an appeal to the spirit of all engineers, ship owners, operators and legislators to help to promote heavy-oil-engine development thoroughly without delay.

The field for the use of Diesel-type engines on board ship is limited at present, but for the propulsion of vessels at speeds of 10 to 12 knots per hr., with capacities of 5000 to 13,000 tons, the heavy-oil-engine installation will be able to hold its own under all circumstances, it being taken for granted that the bulk of the world's trade is carried in vessels of that size; while the cruising radius of oil-engine vessels is unsurpassed. For instance, a vessel equipped with about 1500 b. hp., carrying 625 tons of fuel oil, can attain a cruising radius of about 20,000 miles with oil engines as compared with 8400 miles with a steam-turbine installation, or 7500 miles with a reciprocating

steam installation. On long voyages, at moderate speeds, there are no other installations that can compete, even at the present high prices and the comparatively heavy over-all weight. When eventually motorships compete with each other, the methods prevailing to add superfluous material for safety's sake will be abandoned. This will not only bring down the over-all weight, but also the price of installation. There has been no need during prewar conditions to pay close attention to all this, as the earning capacity of motor vessels was so far superior to that of steam vessels that the present changes were overlooked. Increased use of heavy-oil engines on board ship will naturally improve these drawbacks and the final result will be good if confidence reigns with sincere effort.

The limited field mentioned for the use of Diesel-type engines refers to the average cargo carrier, but when passenger ships of greater tonnage and speedier travel are considered the geared-turbine installation may dominate the field for the time being, even if fuel-consumption figures are higher. Advocates of electric drive for vessels with high-speed turbines do not need to fear real competition from heavy-oil-engine installations as it appears to me at present. A greater number of engine units would be needed to drive generators supplying current to motors attached to the propeller-shaft, as Diesel engines have to be made up in smaller units, in addition to the fact that such units can never be run at speeds allowable for turbines, so that the comparative size of electric generators will not be in favor of oil-engine units. Although it is possible to design high-speed heavy-oil engines running at approximately two to three times more revolutions per minute than is customary when applied to motors driving the propeller-shafts direct, the greater number of engine units and consequent increased number of working cylinders may prove to be a detriment, not only from a standpoint of upkeep, but also on account of the factor of first cost. In addition, a larger crew would be required in the engine room to keep the greater number of parts in workable shape. However, attempts now made by leading American firms to introduce Diesel electric drives should be encouraged and investigated by all means, so that we may know at the earliest possible moment what the best possibilities are. Heavy-oil engines of 4000 and 5000 b. hp. each can be built. They are preferably operated at moderate speed for the sake of propelling efficiency and applied to twin-screw installations. I see no reason for sacrificing efficiency by introducing a transformation process such as an electric drive, for vessels requiring from 8000 to 10,000 b. hp., although there is no doubt about the high efficiency of the electrical apparatus proper. The flexibility in operation of heavy-oil engines has proved reliable in well-designed ships. Attention is called to the fact that not all designs have been successful and that pioneer installations suffered from the lack of knowledge that has been acquired from experience with them. Heavy-oil engines in general should therefore be judged in that light. There was a time when it was not known how to properly distribute the material while designing, when the foundry was not able to produce satisfactory castings, such as are turned out today, when workmanship of the class required for heavy-oil engines was not applied to this prime mover, which created a sensation in the early days due to its high thermal efficiency. That experience is not lost and will prove to be beneficial to the further development and use of direct heavy-oil-burning engines. A combined effort to produce the goods for the sake of the existence of our merchant marine should be made and given first consideration.

Diesel-type engines will hold their own as reciprocating engines until the time arrives when gas turbines can be built to stand the prevailing heat conditions and show equal economy. Meanwhile we should cooperate and endeavor to at least equal and possibly better the efforts of rivals on the seas, for which we have adequate facilities. Referring to the days of Diesel-engine development when mechanical solutions had been found which embodied the inventor's ideas as nearly as possible, the fuel economy was so far superior to that of the existing steam installations and gas engines of that time that a wide area was opened for the use of Diesel engines in the stationary field. The low price of heavy fuel-oil was at that time an additional factor in its favor. This condition, however, does not prevail to such an extent today. Oil producers have kept an open eye on the market and raised prices in accordance with the demand, which is quite justified from a business standpoint; but even under these circumstances the low consumption of fuel oil in Diesel-type installations will put the engines in demand and prove their merit.

Opponents of heavy-oil-engine installations claim that we are not prepared to meet the demand for large engines and are always pointing to what other countries have done or are doing. This is quite right, but at the same time it carries the germ of a lack of confidence in our own production abilities. A visit to shops where successful engines have been produced in smaller sizes than are now sought, and where suitable sizes are now under construction, would clearly show that our products are of sufficient quality to warrant confidence for the future. Another important factor, which is overlooked in most cases and particularly where the price and weight of Diesel engines are commented upon, is that two-cycle engines have not been able to make as much of a showing as have four-cycle engines, owing to the fact that greater difficulties have been encountered in their production. Today, however, we know of two-cycle engines which are reliable and make good records.

It should be remembered that by using two-cycle engines we are able to put 75 per cent more power within the same space, at the same number of revolutions per minute and using the same size of crankshaft, with a corresponding reduction of weight per horsepower; also, when two-cycle engines are substituted for four-cycle of the same power, that the length of the engines is decreased an average of 12 per cent, which also results in weight reduction. In some cases where six-cylinder engines are used, it would be perfectly practicable to use a four-cylinder engine, which would result in a saving of length of approximately 25 per cent.

In an attempt to introduce the Diesel engine electric drive, it should be borne in mind that we are increasing the most difficult factor in oil-engine design; that is, high-speed engines necessary for this work never show the permanent reliability that can be obtained with moderate-speed engines. Although it must be admitted that the weights of high-speed engines compare very favorably with those of moderate-speed engines and therefore make the proposition tempting, we are thus entering a new development which may delay the use of economical power for our fleet at present. The tendency to refer to work performed by Diesel engines in submarines, for instance, does not warrant an attempt in that direction, as it should be realized that increased speed affects the over-all efficiency materially, in addition to the greater problem in overcoming the action of the heat conditions in high-speed engines, which factor does not need much explanation to those who have experience with such de-

sign. The most visible solution for power, for cargo carriers at least, seems to be to encourage builders of moderate-speed engines for direct drive engines of the kind that are now being built in the United States. After we have given the manufacturers a chance to perfect their product and gain additional experience, we could look forward to further advancement in the art. To attempt the most difficult problem at present seems to invite delay; furthermore, we may rest assured that manufacturers abroad are no better prepared than we are for such attempts, so that we would not lose by following this conservative course, as they are mainly trying to bring down the speed of direct-driven engines and place as many working cylinders in a given space as possible. The electric drive, however, has advantages for smaller installations such as yachts, etc., so that the benefit of attempts to develop this kind of drive can be seen from the start.

Cylinder bores as applied to small power units do away with the greater part of trouble in high-speed engines, but for units where thousands of horsepower are required to drive electric motors direct on the propeller-shaft, we are not prepared to meet all conditions, as such high-speed units have not been built for commercial vessels of large size and a great number of small units seem to have questionable value. But let us prepare, cooperate and finally succeed in bringing about a satisfactory solution of this important problem, which is closely connected with the subject of the world's fuel supply.

Considerable reduction of engine-room space will follow the efforts of engineers to design the highest possible power within the least space. It can therefore be expected that rules governing the capacity of the engine-room space may need revision in the future. At present such attempts would be handicapped by prevailing port rules, as a ship with an engine-room space above 13 per cent of the gross tonnage has the advantage over a vessel with an engine-room space of 30 per cent or below, in tonnage allowance for engine room, to such an extent that the extra port charges for a vessel with a small engine room may more than offset the gain due to the extra earning capacity.

Finally, I have a word for the practical man, the operating engineer. In the early days of marine oil-engine construction, the prejudice of steam engineers had to be met. They were particularly opposed to the efforts made by engine builders to enclose crankcases, which eliminated the possibility of touching bearings and crankpin boxes with their hands, because they considered this absolutely essential. Provisions that were made on reciprocating steam engines to sprinkle water on the main bearings and crankpin boxes were necessitated by the gravity-feed lubricating-oil system, but by admitting an abundance of oil under pressure, reliable results are obtained. However, to become accustomed to this different practice seems to create a hardship for the older operating engineers. The younger element will naturally be found to be without prejudice. The idea prevailing from the beginning that marine oil engine manufacturers had solved all problems, and the attempt to adhere to reciprocating steam-engine practice as far as possible, have shown their effects, and all parties have had ample opportunity to familiarize themselves with actual necessities and requirements. The dangerous art of copying without thorough knowledge of all conditions has done its share toward giving a bad reputation to some makes of engines.

A handicap for the United States, in attempting to hold her own on the seas as a maritime nation, is the specifying of the amount of labor to operate the ships. In one instance it was said that American ships could not sail unless practically twice the number of oilers were put on, such decision apparently being based on steam-engine practice. Such rules do not seem to be justified, as modern Diesel installations are as a rule provided with mechanical lubricating systems and therefore require less human attendance.

From experience, I can state that while en route, with things in working order, no hard or strenuous work is thrown upon the operating engineer or his assistants. The general conditions for the engine-room crew are very favorable, particularly when we consider the comfort in warm weather when the engine-room temperatures are very moderate. In port, while inspecting or overhauling, skill is required; for that reason I appeal to the practical man to cast his lot in with those who are trying to make our merchant marine permanent, for the benefit of all Americans, as it can be expected that the training of men to operate such ships as have been described cannot fail eventually to be taken up by the Government or by firms interested in the manufacture and operation of motor vessels.

The Discussion

W. N. Howell:—Concerning double-acting engines with piston rods, I had about two years' experience with an experimental engine having 8-in. bore and 12-in. stroke; we had no trouble with the piston rod. We cooled the rod and the piston by circulating oil in them. We used a long packing of white metal around the rod, in strips or threads which were packed into the stuffing-box, mixed with graphite and set up by a gland until we could get nothing more, then the gland was slacked back a little and it formed a perfect packing. It was a two-cycle double-acting engine with crosshead. We finally obtained about 65 hp. from it. No examples of piston-rod engines have been mentioned. What has been the experience with them?

H. C. Verhey:—If the gland can be kept from contact with the solid matter in the gases, they will not corrode it. With an arrangement whereby the solid matter is carried out through the ports, this might be accomplished. I know of several materials that will stand up and make good packing for a rod.

Mr. Howell:—The exhaust was through a triple row of ports in the middle of the cylinder. The piston uncovered them at the top and bottom of its stroke. The scavenging was done by a cone on the top and bottom of the piston. The center row of ports was for the air; above and below it were the exhaust ports. The ports were at the middle of the stroke. There was still a chance left for solid matter to collect around the rod.

Mr. Verhey:—In the long run carbon enough would deposit to give trouble. I believe we ought to stay away from anything like a gland in such a temperature, if we can, even if it is cooled. If the demand for double-acting engines arises, there are possibilities of obtaining increased power within a certain space without the use of a design having a piston-rod of the type mentioned; for instance, the opposed-piston type like the Junkers engine, having one long cylinder and exhaust ports at the ends, the upper piston being operated by very long connecting-rods. It is one way of getting rid of stuffing-boxes. Some of these schemes appear all right theoretically, although they have not been extensively tried out in marine service. The Fullagar type, partly on the order of the Junkers engine, has two cylinders side-by-side; these are long cylinders with two pistons working in opposite directions, and having the lower and the upper pistons of each

of the working cylinders, which are located side-by-side, connected by means of angular tie-rods. So, there are two pistons working side by side and moving in the same direction. They obtain fairly good efficiency on the crankshaft, in this way. In an engine of this kind we are obliged to build four cylinders per unit. If it is desirable to use a design of this kind as a marine engine, eight cylinders are required because the cranks of the single unit stand at 180 deg., thus having an objectionable dead-center for starting unless an attempt should be made to start on the compressor. I understand that Mr. Setz is now building an engine with an arrangement to start on the compressor.

H. R. SETZ:—Yes; not in the one now building here, but in some of the eighteen that were built in Italy. They start on the two double-acting cylinders of the low-pressure stage; that is to say, with one down and one up.

MR. VERHEY:—I think that is a good scheme for starting, carrying a moderate pressure of 200 to 400 lb.; some carry it higher. In the early stages we thought it necessary to have 60 atmospheres for starting. This air, rushing through a comparatively small orifice, cools the cylinders down to a great extent. This is probably one of the reasons cylinder-heads and pistons do not last long in some cases. We should maintain uniform working temperature.

W. C. DAVIDS:—Should not each power cylinder have its own fuel pump?

MR. VERHEY:—I can say from experience that this is the best way. For example, in a six-cylinder engine having one plunger for each three cylinders, a distributor box was used and leads carried to each cylinder. We found that the length, friction and bends in the pipes are factors which absolutely affect the delivery. This would vary in each case, so that there remains only one satisfactory way and that is a fuel-pump plunger for each cylinder; that is what is adopted by most builders. They are generally integral, but perform independently. The older types are very interesting. The motor ship Selandia has the real history of development. She started with an air compressor driven from the main engine; but only the high-pressure stage, an auxiliary compressor having three stages, delivered air into the starting-air tanks at about 350 lb. per sq. in., which is the approximate pressure that occurs in the second stage of a three-stage compressor. That air was carried to a separate high-pressure compressor, driven by the engine. This system has since been discarded. There has also been a change in the fuel pumps. In the early days distributing boxes were used, but they have since been done away with. The friction in the lines is such that it must be taken care of in a positive way. This is the reason not all engineers approve the scheme that the Dutch are using in order to eliminate a fuel pump. They use a floating vessel filled with fuel oil, with injection air pressure on top of this oil, and with an arrangement which supplies just so much oil, which is carried to the engine through leads from the floating vessel and goes to every working cylinder. The length and shape of these lead lines differ according to the location of that apparatus; also the viscosity of the oil differs at different times, so that the actual discharge is affected and does not remain constant. Adjustments must be made at times, so that the human element is introduced again. The same thing holds true of a gravity-feed lubrication system. It becomes necessary to regulate the feeds at different times of the day. We should get rid of that. We want to have something more positive.

E. A. SPERRY:—What knowledge is there of solid injection systems and the results of engines equipped with them? We have seen on the screen many details of the super-air-compressor, which is really the curse of the Diesel engine. We have heard much about the Germans' contributions in this line, but nothing about any contributions by Anglo-Saxons. The most crying need is the elimination of the super-compressor. This has been accomplished in a practical way. Hundreds of engines are operating in this manner, touching the highest economy in both consumption of air, 2.7 cu. ft. per hp. per min., and fuel consumption. Yet we have heard nothing about this in this otherwise exhaustive review of the subject. I refer to the English contribution by the Vickers company, and I firmly believe we are to hear of still greater practical improvements when the Anglo-Saxon finally gets under way on this problem.

MR. VERHEY:—It is a very good scheme by itself, a scheme which eventually will effect and interest all manufacturers, because with the solid injection system 10 per cent of work in the engine can be saved. A good fuel consumption seems to be obtainable. Engines appear to perform well and reach good economy, but it seems that the combustion is not perfect at all times. I have heard statements to the effect that you could tell a Vickers company Diesel ship by its smoke, from a distance. It is said that with everything adjusted for fixed conditions, at full load and with a certain kind of fuel oil, preferably a light oil, no such trouble is encountered; but when a different load is carried the working principles seem to be affected. This is also one of the reasons other makes of Diesel engine are not as economical during changes of load, because there is no proper means of regulating the amount of air and fuel at different loads under all circumstances. Take semi-Diesel engines or engines of the Hvid type, the latter gasifying the fuel in a little cup before it enters the cylinders. It is perfectly satisfactory as long as the load is constant and the same kind of fuel is used; in general, when all conditions are just so. With a continuous variation of the load, combustion may not be clear at all times; the little holes are carbonized and clog up; then the over-all efficiency is gone. In general, injection air seems to have some effect on the proper combustion and surely has a cleaning effect on all passages where fuel oil and air go together; that is, around the fuel needle. This leads to prolonged economy. There is no question in my mind, however, that we should all look forward to doing away with the air compressor if possible. There is no reason why we should waste a good 10 per cent of work; in addition we would simplify the engine considerably and thus reduce the cost of it.

L. C. MARBURG:—In tests of a two-cycle engine equipped with a Leissner gasifier, we have successfully used Calol oil having about 52 per cent asphalt. The engine was of 20-hp. capacity and operated at 500 r.p.m.

MR. VERHEY:—I have never seen any detail. It seems that there would be no reason for trouble if we could arrange the system so that fuel would be admitted at the very lowest point of the cylinder-head disk, making the arrangement such that no internal firing could take place inside of the fuel-valve cage. If we can put that into practice, it would undoubtedly be an excellent thing.

MR. SPERRY:—We find that there are about eighty engines which run that way. I have some of those nozzles on my desk and they make an extremely favorable impression. As you say, the oil efficiency is high.

ARTHUR WEST:—We want to use oils in this country of perhaps 15 Baumé gravity, which have an excess of 50 per cent asphalt. Is it the opinion that the chances are good for solid injection using that kind of fuel oil?

MR. SPERRY:—Our information is that they can use any kind of oil that will flow. I know positively that they have used Texas oil and California oil. They rate oils in England on a slightly different basis than we do here and talk a great deal about the paraffines. There is no stoppage of the nozzles due to the fuel unless it is dirty.

A MEMBER:—How about the carbon formation?

MR. VERHEY:—Clean burning is the dominating factor throughout. If we could find the means of doing away with troubles of that kind we would be on the right track. Furthermore, I do not know much about the details of the Vickers engine. I know naturally that fuel oil must be broken up before it enters the cylinder. With the needle-valve used, there is a certain distance left between the lower face of the cylinder and the point where the oil is released as a broken-up unit. Traveling that distance, oil may collect again, and it may come out in a body. If we can get a solid-injection system where oil is injected absolutely at the lowest point of a cylinder, no carbonization could take place; and I cannot see why we could not burn clean at all loads, because there is plenty of oxygen waiting. I would say that it might be a matter of design.

MR. SPERRY:—The matter of doing away with the super-compressor is so very important that I am glad to hear you say that it is a desirable thing to avoid. We have evidence, which we believe is thoroughly credible, that a complete set of nozzles in a large pair of engines have run 27,000 miles without being changed. That does not seem to indicate that they are easily stopped up, or that there is a tendency to stop-up from causes internal to the cylinder itself. There is no carbonization that reaches back. It is true that there is a little cavity between the points of the valve.

A MEMBER:—I wish to ask Mr. Sperry regarding the engine with the solid injection whether they finally got good regulation? That is, do they get variable speed, with control from full down to low speed, without trouble, running long periods at low speed? In a single pump in a certain kind of engine, we have used a certain kind pumped by the one pump and handled through distributors to the different cylinders. We were unable to use that and so added 15 per cent kerosene. In another make of engine of practically the same dimensions, in which there was an individual pump for each cylinder, we secured better results with that oil than we did with the lighter oil.

MR. SPERRY:—They operate about as all Diesel engines do; down to about one-third of the speed, perfectly, as far as I can say. The secret of the success of those engines seems to be that there is a flattened tube close up to each one of the injection valves, and then an air-chamber effect at the pump. That combination seems to be the one that is doing the work that I describe.

MR. VERHEY:—I would like to know what happens when the engineer cuts down the fuel to bring the speed of the engine down. Is he regulating the pressure on the system? Does that follow at all times? For instance, without air injection, is any means provided to take care of that regulation? Is a relief valve of some kind used?

MR. SPERRY:—Just a small eccentric on the air-injection-lever fulcrum which makes the cam roller dip down on the cam more or less. Regarding the oil injection, the oil-injection valve at the nozzle is governed entirely as to the duration of its opening by rotating this eccentric. As to the lift of the fuel needle, that system is never governed through the pump at all; it is governed by the above mentioned method, and the lift of the needle is simultaneously varied.

MR. VERHEY:—The same as on the German engine, where much is done by hand. There is a change for the lead with a consequent change for the needle lift. Most four-cycle engines have not such provisions. I have seen it work all right on two-cycle engines and I think it is an ideal solution. It is the coming way, and beneficial when running slow.

H. COOKE:—It has been said that some prefer gravity to forced lubrication. I think there is a place for both. In regard to the gravity lubrication, one important thing in the Diesel engine is to lubricate the cylinders without any excess of lubricating oil. In the trunk-piston type of engine, if we use forced lubrication we are apt to get more lubricating oil in the crankcase than is desirable. Moreover, it is better to use gravity lubrication to avoid excessive cylinder lubrication. In the larger sizes, in which the pistons are cooled, I think when the cooling system is entirely separate from the lubricating oil by a diaphragm, with the piston-rod running through a stuffing-box in this diaphragm so that the lubricating oil has no chance whatever to lodge on the cylinder walls, there is no objection to forced lubrication. We supply the oil through the bearings, crankshaft and connecting-rods in a way very similar to that shown on Mr. Verhey's diagrams. In that case, the diaphragm also prevents any chance of the salt water from the piston-cooling system getting down into the lubricating oil and causing trouble. If the salt water gets into the lubricating oil it will give trouble all through the oil system.

MR. VERHEY:—I believe that forced feed is superior to gravity feed, at least for marine Diesel engines, and shows its particular advantages with the partition between the working cylinder and the crankcase. In engines of the trunk-piston type we have to make special preparations, such as splash guards over the cranks, in order to keep the flying oil from reaching the lower parts of the trunk and the cylinder wall so that, in the case of your 750 b. hp. engine, the forced-feed system would bring you more complication than the gravity system now adopted. The earlier Diesel engines were all equipped with gravity-feed systems, following marine steam-engine practice, but the tendency is clearly shown to abandon it. I had occasion lately to see a 1200 b. hp. Carels engine on the test stand in Milwaukee. It is equipped with gravity feed, is of the cross-head type and clearly demonstrated that the moving parts are throwing lubricating oil in all directions. This is shown at one side of the engine, which is not entirely enclosed, and appears in the form of a vapor. Such vapors naturally spoil the atmosphere in the engine-room, creating a more or less undesirable odor. All this can be done away with in case we adopt an entirely enclosed crankcase, which goes nand-in-hand with the forced-feed lubricating system.

MR. COOKE:—In regard to that odor, I came across a Norwegian engineer and the first thing he did was to smell the openings in the crankcase. He said that is the way to tell whether the engine is operating well.

MR. VERHEY:—When foul gases pass by the pistons and mix with the lubricating oil, carbon is formed which settles on moving parts, particularly on the walls of the crankcase, forming a nasty coating. What vapors mean in a crankcase is clearly shown in engines that have oil-cooled pistons, where the return oil is discharged into the crankcase. This forms a coating of small ripples, which apparently build up in course of time, as observed on Danish engines with oil-cooled pistons. It is far better to carry the return piston-cooling oil outside of the crankcase and thence to the sump-tank independently of the lubricating oil, although they may come together in the

same sump-tank; but the piston cooling oil is preferably returned through a strainer, which holds carbon back. Excessive lubricating oil may make piston rings stick, in which case the gases will flow by, so that I really believe that the enclosed crankcase is the best solution of the problem.

MR. COOKE:—There is one thing that brings gases down into the crankcase; it is an excess of the lubricating oil sticking-up the rings. When the rings are stuck, the gases pass by. It is really the effect of excessive lubricating oil. Another interesting thing is that in the case of our four-cycle submarine engines which have forced lubrication, we take a great deal of pains to keep lubricating oil off of the cylinder walls. As showing the effect of excessive lubrication of cylinder walls the starboard engine of a submarine went fine. The port engine went fine for about five hours and then a fuel-valve needle stuck. We thought that the needle was bent, changed it and ran five hours longer. It stuck again, and they changed the needle in the valve again. Then they pulled the piston up and found it was all gummed-up with oil. The whole trouble was that the lubricating-oil outlet in the base was so located that it did not clear itself properly. We found that by freeing the lubricating-oil pipe the trouble with the fuel valve was eliminated. That gives some idea of the extent to which lubricating oil will go; it went up into the fuel-oil valve.

MR. VERHEY:—On the first engine for submarines that we designed, considerable trouble was encountered in keeping the lubricating-oil consumption down. It was extremely in excess of what we expected, and we had to experiment in building proper splash guards. The exhaust showed a white smoke and to determine whether this was lubricating oil, to satisfy ourselves thoroughly I heated a piece of iron, dropped fuel oil on it and noted that the smoke coming off was black; whereas, that of the lubricating oil showed a blueish white. A man asked me a question about the little pump located near every cylinder and we learned that oil was supplied by a rotary pump and discharged in a header running along the engine, small leads therefrom going to each working cylinder. The engineers must have been under instruction to work these little pumps by hand at certain intervals as determined by practice, as there is no question whatever that lubricating oil must be discharged against the working piston at a height approximately between the second and fourth ring. The working pistons had a wiper ring, but I did not see splash guards. How this is worked out I do not know.

MR. COOKE:—I noticed on the submarine engine we visited that it seemed they were lubricating the cylinders right off of the main forced-feed system. They may have something in the cylinder walls that regulates that oil to the cylinders.

MR. VERHEY:—Mr. West, have you noted the fact that oil can be splashed against the wall and not creep up and gum the ring?

MR. WEST:—Not on that particular engine, but before the war, in one of the German yards, I saw an arrangement in which the connecting-rod went up into the piston, there being a shield over the bottom of the piston. But they made the sheet on a radius concentric with the crosshead pin, and then formed on the connecting-rod a shield which covered it nearly all the time. This very nearly covered the slot. During the war the Germans were very short of lubricating oil, and it not only would have been very disastrous to them to waste oil to such an extent as to get on the rings, but they also would have lost the oil. One of the things which was putting them out at the end of the war was lubricating oil. I think we can be quite sure that in some way they did surmount the difficulty on this German submarine-type engine.

MR. COOKE:—On the smaller engines, they have done away entirely with direct cylinder lubrication in the Swedish factory. They get enough lubrication from the splash, the oil getting up to the cylinder walls from the moving parts.

A MEMBER:—Mr. Cooke made a remark about lubricating oil getting up in the fuel valve. How is it possible for it to get in there through the cylinder?

MR. COOKE:—I cannot account for it.

MR. VERHEY:—Through the spray?

MR. COOKE:—Just through the nozzle. We cannot tell just why it did that, except that we did know that while the excess lubricating oil was there the fuel-valve needle kept sticking. We then took it out and found that it was all gummed up, and after the lubricating-oil overflow pipe was freed, so that there was no excess lubricating oil, there was no more trouble with the fuel-valve needle.

A MEMBER:—Could it not get through the nozzle?

MR. COOKE:—I do not see how it could, but the actual fact is that the needle kept sticking. I think it stuck a dozen times.

A MEMBER:—I was there and studied the question. They took their oil from the small branches that led to the cylinder. They have a valve there which is shut off when the engineer opens the valve and admits oil.

MR. VERHEY:—It is simply a question whether or not it splashes. Mr. Jackson can tell whether an engine can run on lubricating oil. Did you not have trouble with the drain in one of your Diesel engines?

L. B. JACKSON:—We had a 75-hp. unit and when the drain in the base plugged and the engine throttle was shut off, it would run on the lubricating oil for a considerable length of time; but that happened only when the engine was overheated. It would run on the lubricating oil until the temperature dropped considerably. It must be a typical experience.

HERMAN LEMP:—In our Erie yards we have been operating for some time a 200-hp. two-cycle oil engine, used in connection with electric drive, for switching cars. This oil engine has an enclosed crankcase and the lower portion of the pistons are provided with scraper rings to scrape off any excess of lubricating oil thrown against them from the crankcase. In spite of all precautions some of this oil will go by the scraper rings and show itself as a blue haze in the exhaust, and some will over-lubricate the regular piston rings and cause them to gum up. The lubrication of these rings has been provided for by a positive-feed McCord lubricator and, since it was found that with a closed-crankcase type of engine oil will go past the scraper rings in more or less quantity, it was thought that this amount of oil would perhaps be sufficient for properly lubricating the piston rings, and that what was really needed is a means for thinning out the oil in the piston-rings to prevent them from gumming. Consequently we started several months ago the practice of replacing the lubricating oil in the McCord lubricator by pure kerosene, and ever since this practice was inaugurated the rings have remained open, were found to be sufficiently lubricated, and the blue haze in the exhaust has completely disappeared.

MR. SETZ:—Concerning over-lubrication, I wish to cite a case from my own early experience where this became a feature of advantage. It was on one of the first high-speed four-cycle engines built in Europe. The fuel consumption guarantees were such that when it came to the final test we could not quite attain them. The en-

gine was lubricated by circulation of oil under pressure at the different bearings and connecting-rod boxes; in our desperation we increased the oil pressure and the fuel consumption at once decreased so that we easily met the guarantees. Today, an account would certainly have to be given for the gray exhaust which was caused by our method of "improving" the fuel consumption.

MR. SPERRY:—This strange effect which occurs in Mr. Cooke's spray valve might be very easily explained. If the lubricating oil gets past the rings up into the combustion space, it is there in the form of fog or vapor. Just at the moment that super-compressed air comes in, there is a refrigerating effect, the fog will tend to condense at that point and the oil will collect at the coolest part, which is, of course, the nozzle. I think possibly that might be just what happens.

MR. VERHEY:—It appears so.

MR. MARBURG:—We found in connection with coke-oven gas that the damage done by sulphur was particularly great in the presence of an unusual amount of water. The reason for this is quite evident. Is there any way of keeping the humidity out of the oil, if oil containing a large amount of sulphur is to be used?

MR. VERHEY:—If we heat it, we will do away with some of the water.

A MEMBER:—You have to heat it considerably to boil the water out of it.

MR. VERHEY:—No, we do that this way. We pump the oil from the bottom tanks to an elevated tank between the shaft tunnels, where it has a preliminary chance to settle, and by taking the oil off at a high point we have a good opportunity to leave most of the water behind; from there on it goes to the daily supply tank where it stands about 12 hr. and, in case we are using heavy oil which must be heated, we are in a still better position to get rid of water in the oil.

A MEMBER:—The trouble we had was with the exhaust valve, almost entirely; it was not with the pistons or other parts. The two-cycle engine would be free from that objection because it uses port scavenging and there is no exhaust valve as such.

MR. VERHEY:—I think that two-cycle engines are far better off in that respect.

MR. COOKE:—In some investigations made in Germany after the engine ran for some time it began to labor. Upon investigation it was found that it had excessive back-pressure. It was found also that the exhaust pipe was filled with a deposit of sulphate of iron. The reason was that the exhaust pipe was so long that at the end it cooled below the dew point, so that the steam in the exhaust gases, caused by the hydrogen in the fuel burning to H_2O, condensed. That picked up the SO_3 in the exhaust gases, caused by the sulphur in the fuel burning to SO_2, and made sulphurous acid. The SO_3 I believe would be inert if it was anhydrous, but when it was picked up by the water it was very active; it attacked the iron pipe and filled it up with sulphate of iron. I believe that is an unusual case.

A MEMBER:—Is it possible to use 6 per cent sulphur oil in the Diesel engine?

MR. VERHEY:—In two-cycle engines it might not be noticed so much as in four-cycle engines. Whether it is very desirable in the long run is another question, but not many oils contain as much sulphur as that. On a four-cycle engine trouble might be experienced earlier than with a two-cycle. As a matter of fact, most manufacturers specify a limit from 2½ to 3 per cent. In general, any oil can be used that can be burned under a boiler, where excessive sulphur would also give trouble; although a little better condition prevails, as steam may have a cleaning effect on the nozzle. Some manufacturers claim not to be at all worried about the sulphur content in the fuel.

A MEMBER:—Does that trouble appear as a lubricating trouble or in the pitting of the valves?

MR. VERHEY:—In the pitting of the exhaust valves; it also affects the cylinder walls.

A MEMBER:—In building gas engines to operate on gas from coke ovens and also on gas from oil stills, we built many four-cycle engines for the Standard Oil Company to run on oil-still gas. The sulphur does not as a rule pit the valves, unless the engine runs a considerable portion of the time at rather light loads. At heavy loads it does not cause pitting. At light loads, temperatures get down to a value that will cause pitting. I think it is reasonable to suppose that gas engines using this oil-distilled gas is roughly a parallel case to Diesel engines using sulphur fuels. That is our experience.

A MEMBER:—Will an open and a closed nozzle each handle low-gravity oils with the same satisfaction? Take, for instance, an oil of 14 deg. Baumé gravity.

MR. VERHEY:—The advantage is at all times with the closed nozzle, where we have control to force the oil through. In addition to that, assuming that you refer to a case where injection air is used, the cleaning effect of injection air puts weight in the scale too, as it forces and takes the last particles of the fuel oil off surfaces where they might otherwise hang, carbonize and give trouble in the end.

A MEMBER:—Just how low in specific gravity can an oil be used in the Diesel engine?

MR. VERHEY:—As low as 12 deg. and we can use any oil which will flow through pipes. If too low a degree Baumé, we must heat it to be able to handle it. Any oil that can be used under a boiler; such oil as we are using in our oil-burning ships can be used in Diesel engines if we choose to use it.

A MEMBER:—Are you putting in heating coils?

MR. VERHEY:—We will have to lower the viscosity of the fuel oil either electrically or by means of steam, so that it will readily flow through the pipes. This is an interesting point, as on several occasions I found that conclusions are drawn based on what practice is followed by European builders of four-cycle engines and in successful ships that visit our harbors regularly. They want to take no chances, absolutely following the way of least resistance. Their engineers are under instructions to buy nothing less than 24 deg. Baumé oil, as this is the kind of oil suitable for their particular design of fuel valve and all adjustments have been made accordingly. It has occurred that heavier oil proved to be troublesome for these particular types of installation, whereas other types having a differently designed fuel valve might have been able to use this oil satisfactorily. Mr. Cooke can tell us about that, as several of his four-cycle engines are successfully running on Mexican oil of very low gravity. Two-cycle engines are in a better position to use heavier oil. For that matter, large two-cycle engines of the Nordberg type now running in New Mexico have been successfully using 12 deg. Baumé oil for a long time. Some time ago I found that some of my professional friends in a search for handicaps for Diesel installations were not entirely satisfied with my statement regarding the possible use of oils heavier than those used in the installations mentioned, and were apparently of the opinion that 24 deg. Baumé oil was the best that could be done in Diesel engines. In an effort to go down to rock-bottom facts, I consulted such men as Mr. West, Mr.

Cooke, Max Rotter, Mr. Jackson, Mr. Nordberg and Mr. McCarthy, all of whom sent me a résumé of their experience and opinion, really showing that there is no objection whatever to the use of heavy oils in either four or two-cycle Diesel engines. I hope to embody the various remarks of these engineers in a later article. It is not the quality of the fuel oil that should worry our competitors advocating steam-driven power, as the only important questions are the weight and price of Diesel installations, because their economy cannot be questioned, even if we should be compelled to use more expensive oils. European-made installations, now closely watched owing to their success, are using higher-priced oil than American oil-burning ships, for no other reason than that while they were practically holding the field alone the oil they most desired was easily obtainable, and, owing to the great cruising radius of their ships, they could bunker a sufficient quantity so as not to become dependent on the local supply available at different places in the world. I feel sure that eventually all manufacturers will attempt to adjust their designs to meet the change of conditions.

A MEMBER:—The two-cycle Diesel engine has some theoretical advantages over the four-cycle, such as the working stroke, smaller bore, etc. We have the experience of the Italians, who build two-cycle Diesel engines of the same horsepower as four-cycle. They find that there is absolutely no gain on account of the pumps, scavenging apparatus, etc. What would you advise, to use only the four-cycle engine or not?

MR. VERHEY:—That brings the issue to a focus. There is practically no competition between motorships today because there are not enough of them, but when competition comes the ship owner will look first of all to what the installation will cost and how much cargo he can carry in the ship that he intends to equip with oil engines. We know that the two-cycle engine can be built shorter than the four-cycle, for the same horsepower. Therefore, there is a gain in weight and a gain in cargo space; also, if we should follow a line of development doing away with direct-driven pumps, it is possible to make an engine-room arrangement whereby the space can be utilized far better than before. The general layout of engine rooms being practically identical, no matter what the make of engine, practically the same general arrangement is seen in motorships equipped with four-cycle engines, that have a reputation. All that will change. With a number of American companies interested in the development of motorships, improvements can be expected which will abolish all trouble, and the two-cycle engine will be the coming marine engine. What we want is the lightest engine in the smallest space. The two-cycle engine can be built in simple form, without question. I have designed high-speed two-cycle engines varying from 300 hp. to 900 hp., all sizes, with six cylinders. A 500 b. hp. four-cycle engine having a piston speed as high as 1100 ft. per min. was also successfully built. These two-cycle engines based on the principle of double-port scavenging were placed in some of our submarines and have been a good demonstration that, with proper design and workmanship, it is possible to produce maximum power in a limited space. We had to satisfy the Navy Department and show that two-cycle engines could be made to run and stand up, as there was little confidence prevailing owing to the failure of other types. The future development of larger types of two-cycle engines will see the top scavenging principle come to the front again. In any engine we have to look for a scavenging process whereby the exhaust gases are not penetrated but expelled in such a way that there is a minimum disturbance of the column of exhaust gas to be driven out through the ports at the lower end of the working cylinders. Difficulties encountered in the early days with cylinder-heads and pistons can be overcome, so that the way of least resistance by eliminating valves in the head need not be followed any more. I predict that the two-cycle engine will be the coming engine, not only on the strength of my last statement, but also owing to the consideration due to builders of opposed-piston-type engines which invariably work on a two-cycle principle. When competition brings us to the point where space requirements on board ship are the main factors, it is evident that the opposed-piston types offer an additional step in that direction, where two-cycle engines have already an advantage over the four-cycle type. However, it should be borne in mind that the opposed-piston type engine has one distinct disadvantage for marine work, because of its height, which becomes an appreciable factor, and overhead weight in a ship is very undesirable. Such engines may perform well on the test stand, but when placed in a ship conditions differ greatly. I saw a Lloyd's survey of the motorship George Washington showing the wear of cylinder walls at one side of the athwart ship center line of the cylinders. It remains to be seen what the performance will be of these tall engines, of which no data based on extended service are available at present. There is a natural tendency for the pistons and liners to wear toward the inboard side, but the motions of the ship affect the wear also in other directions, as disclosed by the Lloyd's survey mentioned.

A MEMBER:—Do the tips of the screws turn outward on the George Washington?

MR. VERHEY:—Yes, for the sake of propeller efficiency. In addition to what I said about the wear of cylinder liners, this was practically the same for all of them. In connection with this peculiar wear it also occurs to me that the consideration given to introducing opposed-piston-type engines for direct drive, which save space, must go hand in hand with the problem of installation of auxiliary power for cargo handling. The tendency to increase the speed of cargo handling requires higher-powered engines for which existing installation practically determine the length of the engine-room and, when we consider that it is desirable to refrain from making recesses in bulkheads for the sake of a clean hull construction, it can be seen that much study becomes necessary. I am convinced that problems of that kind will occupy the minds of many engineers interested in the production of motorships.

MR. LEMP:—I am in favor of the two-cycle engine. In 1911 H. G. Chatain and I were instructed by the General Electric Co. to go abroad and study the Diesel engine situation; we canvassed all Europe. The instructions were to produce as light an engine as possible, with not necessarily light materials, suitable for traction purposes or for vessels as electric generating units or as small stationary sets. We selected a type generally known as the Junkers, and produced a 150-kw. engine which weighs 90 to 100 lb. per horsepower as a stationary set and runs at 500 r.p.m. Being of the double-opposed-piston construction, it has absolutely no valves for the working cylinders, the pistons themselves uncovering the ports. We gave a 20 deg. lead to the cranks, so that the exhaust port would close before the scavenging port starts to close. These engines have been running for a number of years at two different stations in the Philippine Islands and in Porto Rico. We use on these engines hydraulically-operated steel plungers for fuel pumps, *without any*

suction valves whatever. They are known as variable-zone, but are constant-stroke pumps. The weak part in any pump is the suction valve. The barrel and the sleeve of the pump are of glass-hard steel. The pumps ran for three years and none has been replaced as yet, to our knowledge. There is no packing to watch; governing is very nearly perfect.

In connection with Mr. Chatain, who is the head of the gas-engineering department of the General Electric Co. in Erie, I have given considerable thought to the question of ship propulsion. We have substantially come to the conclusion that instead of building large, bulky engines which involve a considerable amount of weight, directly connected to the propellers, we shall follow the practice of the marine steam-turbine development, and introduce electric drive between the propeller and the prime movers. We have laid out tentatively the power equipment for a cargo ship requiring 3000 hp. on the propeller. We find that we can put into the space now taken by the steam turbines, disregarding the boilers absolutely, five of the six-cylinder units of the Diesel-type engines referred to and two two-cylinder units for auxiliaries. The latter can be stowed away in any manner desired because the electric drive does not force us to place them in any definite position with respect to the propeller-shaft. We can put them crosswise or in whatever position seems best. The idea of having something like thirty cylinders, or double the number of pistons, for transmitting 3000 hp. may look radical at first sight, but when we consider the matter from the viewpoint of manufacturing and replacements those who have built automobile or Liberty engines in quantities know how low production costs can be cut down when a large number of parts are built. In a steam turbine a large number of small elements transmit the motion of steam to the shaft. Suppose, for instance, a machine with a large number of small pistons connected to one crankshaft. That would be an absurdity, but we can accomplish the equivalent by using a number of small, compact electric direct-current units, and couple them in multiple electrically, keeping one in reserve. In case of any trouble we simply cut out one set and still have the others to go on.

MR. VERHEY:—I have heard and thought much about the electric drive. The fact remains that we have 36 cylinders with all their fittings. The merits of this solution seem questionable at present, in view of the fact that we are losing efficiency by this transformation process very much on the order of the burning of fuel under a boiler and losing valuable heat units, which is the reason for the low thermal efficiency of steam installations. The handling facilities of an engine of 3000 hp. can be made very simple and thoroughly reliable, which also holds good for larger units. I consider it possible to build units for direct drive of 3000 to 4000 hp. at 90 to 100 r.p.m., which meet all present demands for cargo carriers. Why, therefore, should we use a transformation process? The manufacture of six cylinders to a unit offers also a chance for cheap production, in addition to the fact that high-speed engines can never show the endurance that can be attained in moderate-speed engines.

We hear statements advising the use of the surrendered German submarine engines and their installation in ships for electric propulsion, but my experience with both high and low-speed engines leads me to state that I cannot believe at present that we should resort to high-speed engines for installation on board ship. Repair bills will run high and a larger crew of electricians and engineers must be carried.

MR. LEMP:—We have chosen a speed of 500 r.p.m. We saw an engine run this afternoon at 450 r.p.m. and I think that speed was not abnormal. In order to save weight we must increase speed. I believe that 500 r.p.m. is not excessive for a 150 kw. or 750 hp. engine. Quite irrespective of the ease of reversing, a propeller-shaft driven by an electric motor at constant speed has advantages which no reciprocating drive will approach. In a rough seaway, when the propeller comes out of the water, there is no necessity for having an engineer at the throttle or an automatic regulator to take care of this acceleration. It will be taken care of inherently by the very fact that the speed is constant, irrespective of load. This is very important. Our electric drives on battleships have shown that we can place the motor right in the aft part of the vessel; and instead of carrying a long shaft, the motor can be coupled-up short to the propeller, which in itself is an advantage. Regarding the multiplicity of parts in small engines, I feel that this is not such a great objection as it may seem at first glance. When we come to analyze it, we can introduce manufacturing methods which we cannot introduce in large engines. The type of engine to which I have referred has no cylinder heads and valves. The cylinder is simply an open tube with two rows of ports, and has two pistons moving in opposite directions. The scavenging is very good; the engine is simple to maintain.

For comparison, we had the same workmen and shop organization construct a 100 kw. four-cylinder four-cycle Diesel engine, to English drawings, and a 150 kw. two-cylinder two-cycle, opposed-piston type engine, of our own design. These two were erected side-by-side on the same platform. The weights of the two-cycle engine were considerably less than those of the four-cycle. The noise of the two-cycle engine at 500 r.p.m. was much less than that of the four-cycle at 450 r.p.m., and the operators greatly preferred the two-cycle engine. An engine of this type can run at high speed without much trouble because there is not such a mass of valves. The port openings are easily cared for.

MR. VERHEY:—I must admit that the feature of an opposed-piston type engine, which does away with cylinder-heads and valves, is well worth considering. I also know that in this case the number of revolutions can be increased without trouble, due to better balance; but high-speed engines will wear more and endurance may be a big factor. We have not tried this proposal. Let us say, however, that your proposition has points worthy of consideration, and therefore should not be severely criticized at this time. If you can make these engines endure, they might be successful.

H. A. SMITH:—Will Mr. Lemp tell us whether in making the arrangement for those small units he took into consideration the unstable condition of a vessel and the end-play that might develop from that?

MR. LEMP:—Yes.

MR. WEST:—In connection with the suggestion of small electric-drive engines, I take it that we are referring to commercial engines and not to warships. I am referring to commercial ships only. We have a company whose business it is to operate a considerable fleet of ore ships. In discussing this matter I have had it brought to my attention very forcefully by our steamship operators that in America the supply of engineers for 90 to 100-r.p.m. engines is more plentiful than of engineers for 400-r.p.m. engines. They make a cardinal point of that. They say that we must operate with very bad chiefs, as a rule, because we cannot get better ones; and they seem to think that is one of the governing principles

of designing any form of marine prime-mover, that the kind of men that must be employed has a tremendous influence. They would oppose the small high-speed electric drive for that reason. Ordinarily, we refer to tramp commercial ships, and it is hard to obtain engineers who are sufficiently familiar with electricity and the operation of a considerable number of high-speed engines. These are not my own opinions, but things that have been said to me a number of times. I take it that the demand of our fleet operators is similar to that of those who operate the same kind of ships in other lines.

MR. VERHEY:—We realize these facts are true to a certain extent; we cannot say that in America we have the men just now. Every country has the same difficulty when it comes to internal-combustion engines. If we cannot rely on our practical men and make them see that they should be willing to grow with the progress of requirements, we will be very badly off, but I cannot believe that we will suffer from that very long. We had also to train turbine engineers, but today we have good men. I for one do not think it is necessary to feel satisfied that the present conditions will always prevail. If it were so, we had better step out of the marine business and deliberately leave it to other nations to train men.

A MEMBER:—How does Mr. Lemp figure the cost?

MR. LEMP:—As a manufacturing proposition, with a large number of small and equal parts you can jig up effectively in place of having complicated layouts. Furthermore, the chances of losses by blow-holes, cracked cylinders and defective castings are very much lessened when there is a large production of one size only. As far as the electric drive is concerned, it would not be difficult to get a mechanical efficiency of 90 per cent from engines to propeller. From the maintenance viewpoint, apparatus of that size is much more easily standardized and made interchangeable, so that repairs really mean replacements of parts by spares fitted to gages, in lieu of hand fitting by experienced marine engineers of the old school. From the operating standpoint, reliability is assured by subdivision into a number of units independently operative and easily connected to one common bus, so, while at first glance the proposition looks absurd, when we come to look into it we find that it has advantages from a manufacturing standpoint.

MR. COOKE:—In regard to marine engines, we use slower speeds than is the practice of other manufacturers. That has been our practice also in connection with stationary engines. We have made a very careful investigation of the subject, both here and abroad. In Europe, they tried to bring out the high-speed Diesel engine to take care of the stationary engine business, to match up with the high-speed European generators, but they found that the slower-speed engines were the best. One of our guarantee engineers told us that the small high-speed marine auxiliary engines should not be used. He advised getting, if necessary, a slow-speed stationary engine, even if it were heavier and cost more, because engines of that type do not require as much attention as the small high-speed engines.

MR. LEMP:—One point must not be lost sight of; the thermal efficiency of the Diesel engine is already very good when it reaches 150 kw. In fact, it is from 28 to 32 per cent per b. hp. with the two-cycle type. Very little is gained by using large sizes. The efficiency may reach 34 per cent, but as a general proposition the great gain is in the small unit. There is no great proportional saving in the large unit over the smaller one.

MR. VERHEY:—The statement that there is no great saving in thermal efficiency above 150 kw. is correct, but it will be granted that the mechanical efficiency of high-speed units is considerably lower than in low-speed engines, which is also a factor for consideration, and affects the fuel consumption which will count during years of operation. When we are satisfied that engine units as they are built today are unnecessarily heavy and in some cases lack proper accessibility and handling facilities, when we believe that the last word in engine design toward direct drive has been spoken, there might be ground for argument, but with the interest that the world takes at present in oil-engine production, with so many brains working, we will eventually see that engine units of from 3000 to 5000 hp., such as are in demand for cargo ships, will give us no more trouble than our present steam installations, perhaps less. In fact, a single-cylinder two-cycle engine of 2000 hp. running at 90 r.p.m. was produced and ran on the test stand in Europe. I personally witnessed this in 1914. On the strength of this, I would not be surprised to see that with proper financial backing units of 12,000 hp. could be built, which, for instance, would be sufficient to propel a battleship of the size and speed of our Oklahoma, a twin-screw installation with reciprocating engines. I remain of the opinion that the life of low-speed engines will exceed that of high-speed machinery, but as long as there are so many angles of consideration and we engineers are called upon to solve problems to suit various requirements, I appeal to all engineers in an effort to assist the United States to meet the competition of other nations, even with our handicap of higher cost of production, as we do not lack manufacturing facilities. We should all render our share of the work, no matter what the nature of the problem may be. I also invite the technical office forces in our shipyards, and others now engaged in different lines of marine work, to pay due attention to changes which are sure to occur, so that we may become prepared to meet all problems in the most efficient way. This can also be referred to automotive engineers who have already made such a wonderful showing by practically standardizing the whole automobile industry. Their experience has been of great benefit to those who have specialized in the heavier installations of greater power. Technical men who have made a life study of certain lines should not close their eyes and feel satisfied that the things we have now will last; we cannot afford to take such a position in these times of rapid changes. In this way we shall carry America to the front in this comparatively new line of marine propulsion. Encouragement should also be extended by our Government to all concerned to reach a satisfactory solution of the world's fuel problem for the benefit of our nation in general and the permanent existence of our merchant marine.

A MEMBER:—All marine work must be simple. It does very little good to save fuel and lose the ship. I know a man who argued that the Corliss was the most economical steam engine. It was put on a 9-in. compression cylinder, a complete Corliss gear, but they never built another. A marine outfit is complicated enough without adding any further complications; it must be simple. The reason that the marine engine has been so successful is that it is simple. The engines which passed through English hands were simplified before they went to sea. Engineers have enough difficulty without introducing complications.

MR. TAYLOR:—One thing developed in a Diesel drive coupled to a gear. The coupling is a magnetic coupling. I believe they are working very hard on it and expect fine results. Personally I do not see why that should not be an excellent thing. We have had in the United States much trouble with gear drive. A gear might be made

to run successfully. We have in the United States today vessels that have run 50,000 or 60,000 miles without the least trouble with their gears. It appears to me that the Diesel engine running through a magnetic coupling would give a simpler drive than the complicated electric drive.

The question of obtaining engineers is a matter of training them. The American personnel is very quick to learn. In my experience in investigating gear turbine troubles in the service about 80 per cent have been due to inefficient operation, 15 per cent to poor workmanship and 5 per cent to poor design. We have done things today which in my opinion are wrong. We send men to sea with insufficient training. We do not let them see the engines erected in the shops, but put them on our vessels very often a week before they sail. They do not even see the dock trials. I think that the simpler the drive the better, but if we take the personnel we can obtain in this country, put them in the shop where any particular type of machinery is being built, and give them a chance to know the engines we expect to run, we would undoubtedly get better results. The Danish Company's men spend months in their own shops and they send one of their own specialists aboard ship. That is why the company has had such phenomenal success with its vessels. There is no reason this country should not have the same success.

MR. VERHEY:—I think that the training of engineers should be given utmost consideration. We really cannot afford to let things continue in this respect as they have been in many instances during the war emergency.

MR. JACKSON:—We are going to have all the auxiliaries, cargo pumps, engine auxiliaries and electric drive. In the case of the chief engineer in this particular ship we sent him to the shop where the engines were built and he went through with the engines. He was also there during the building of engines of another size, and he has been chief engineer on the boat with the other engines. We have had absolutely no trouble with those engines, showing that the man has been given proper education as to the manufacture and installing of them. We were, however, much troubled with the operation. This particular man we considered an exceptionally good Diesel engineer. He never knew anything about an electric motor or generator. We tried to teach him something about them and could not.

With regard to the space requirement, that is not always the whole thing. It is possible to get a ship which will have more space in it than we can fill with cargo. In such cases the space does not count. It is the saving in dead weight or machinery weight. In the case of the ordinary tanker if we can save fifty feet that will not help as much as 100 tons' saving in weight.

MR. DAVIDS:—Referring to the connecting-rod, at the New York Navy Yard the wrist-pins in Diesel engines continually burned out for lack of oil. The oil failed to pass up the connecting-rod; a ball check was therefore placed in the large or crank end of the connecting-rod, which held a column of oil. This prevented the burning out of the wrist-pins.

MR. VERHEY:—Referring to Fig. 7, such a construction has been used on smaller type connecting-rods than these. For instance, some builders use this method of lubrication on their compressor connecting-rod. In the case shown it is only a matter of keeping up sufficient pressure, which depends on the fit of the bearings. If the clearance is too great or if there is a poor fit in one of the bearings, the oil will merely spread and lose its pressure. When we keep a restricted clearance, the pressure builds up in the grooves in the bearing boxes and there is no doubt that the oil will land where we want it; this is done successfully in most merchant-marine Diesel engines. However, the suggestion is good, and in cases where we have not a sufficient supply of oil at hand it will help, because the oil will be accelerated and go up.

A MEMBER:—Were there three auxiliary engines such as are shown in Fig. 8?

MR. VERHEY:—Yes. On the 12,500-ton ship now under construction for the Emergency Fleet Corporation, we have engines of 2250 instead of 1500 i. hp., such as those on the George Washington, on which I made a long trip. We also maintained three sets, which, however, depends on the number of winches we choose to use and the speed at which we want to handle cargo. As a matter of fact that is where the point comes in; Europeans are not up to the point yet where they consider it essential, as Americans do, to take their cargo out in a very short time. It does not amount to so much in dollars and cents to them as it means to us when a ship lies for a number of days in port longer than necessary. As a matter of fact, we have now adopted European-built winches as suggested, on account of the fact that we had no choice in selecting an American-built winch of suitable proportion.

A MEMBER:—How will that 12,500-ton ship be heated?

MR. VERHEY:—It will have a donkey boiler of about 100 sq. ft. heating surface and at about 100 lb. pressure. It will therefore have a steam-heat system, which means that we must install pipes and radiators and that we take chances in the winter that they will freeze. We will have to run our leads on the deck because we seem to lack confidence in the electrical equipment which, however, in my opinion should be as safe as possible, although probably more expensive. At least one company has already installed such an electric equipment.

MR. JACKSON:—We installed electric heating in two small harbor tank ships of 70,000-gal. capacity and found it satisfactory. In a large motorship now under construction, we are installing electric heaters in the quarters in the bridge-house and in the forecastle. In the after-quarters we are using hot-water heating. That the entire vessel is not electrically heated is due to lack of generator capacity for maximum load when all heaters and all cargo pumps are working.

MR. VERHEY:—That introduces the subject of electrical capacity. With several auxiliary sets standing idle we can apply current to the system electrically and eliminate all piping. It is the coming method. We wish to get rid of oil. We raise, however, one point that might be of slight advantage at present. In certain instances we desire to heat the fuel oil in cold weather. To do this we carry a steam-heating coil into the elevated tank, but to use it steam must be generated in the donkey boiler, which is a lengthy process. At the same time we would need to modify our practice regarding the auxiliary compressor for high-pressure air which is carried as one of Lloyd's underwriting requirements. This has reference to the 1000-lb. air compressor which is used for starting auxiliary engines in case all other compressed air is lost. This is made steam-driven on the majority of European ships. In that case we would have to install a small oil engine.

MR. HOWELL:—Would the inefficiency of electric heaters be a detriment, in a passenger ship, for instance?

MR. VERHEY:—We realize that the efficiency of electric heaters is not great, but when we come to figure the matter out, from all angles, the fact remains that we have the power there, standing idle during the voyage, so that we might as well use it when weather conditions so re-

quire. Regarding passenger ships, I think we can afford to put in an electric heating system. When it comes to the ordinary tramp ship, that is doubtful, but at all events it does away with undesirable steam lines, etc., and makes a cleaner layout.

MR. HOWELL:—In a two-cycle engine have you experienced any trouble in the scavenging air compressor? When I was with the Lake Co. we had a Sulzer engine built in Switzerland and at 500 r.p.m. we found that the scavenging could be done with a very much smaller scavenging compressor, but on account of maneuvering we had to use two 30-in. low-pressure compressors for scavenging, so that those compressors at a high speed put such a load on the engine that we had much trouble in getting the fuel consumption per brake horsepower that was required.

MR. VERHEY:—If we could take that pump away and have it independently driven, making it meet varying conditions, we would do the right thing. As long as we drive direct we must consider being prepared for the worst condition which we may have to meet, but submarine engine designs, to which you probably refer, do not leave many choices, owing to the limited space in the boat. I know that the pumps are of liberal proportion, but we did not find trouble in meeting the fuel guarantee, as the proportions of the working cylinders were ample.

MR. WEST:—In connection with that Skandia-Werkspoor engine for the U. S. Shipping Board, the exhaust pipe is immediately over the axis of the cylinders. Must a section of the exhaust pipe be taken off to take off the cylinder?

MR. VERHEY:—To take the cylinder head off, we are compelled to take off the liner also. It is inserted in a box. So, to remove a cylinder, one of the sections must be taken away. This is one point which is adopted right along and considered by the Dutch as the only thing to do. They use an exhaust header all the time on top of the cylinder. It does not seem exactly right for the reason that it involves additional weight at the top of the engine. In some engines we get such a critical point of cross vibration that we do not know where it comes from. When the exhaust header is taken away, we do not invite that chance. I think that the Danes see that, because they support the exhaust from the deck, which is good practice in my opinion. In designing these engines the Dutch practice was so typical that there has not been one company that did not fall into the same old troubles.

A MEMBER:—On the Skandia-Werkspoor engine, can the piston be taken out from below?

MR. VERHEY:—Yes, that is a good feature which I believe no other engine has. An extension or skirt on the cylinder is under the box. The rings can be seen and checked, and the carbon can be cleaned off when desired. When the cylinder-head can be lifted the whole thing can be taken out; in this case the connecting-rod and the piston-rod can be left in place. The upper flange of the piston-rod is disconnected and the piston is shoved out. A special arrangement is made for this, attached to the columns.

A MEMBER:—Must the piston be disconnected and pulled through? Are telescope tubes provided?

MR. VERHEY:—Yes. I believe that is done by disconnecting several bolts on the flange which is located on a partition. The crankshaft can be taken out by removing part of the columns. Most engines do not have such facilities.

A MEMBER:—Referring to the bed-plate for the 825-hp. Skandia-Werkspoor engine, how is the lower base for the bearing shaft held?

MR. VERHEY:—That is known as a Dutch dowling. It is a difficult piece of work; a special jig has to be made.

RESEARCH NEEDED IN THE PETROLEUM INDUSTRY[1]

FACED with the growing need for petroleum, we have to consider seriously the means whereby an adequate supply for the future can be obtained. To-day there are many laboratory processes which have not been developed. One object of research would be to test out on a commercial scale many of the laboratory processes now dormant commercially because of insufficient funds. Another object of research should be to correlate the pertinent facts of all investigative work and start supplemental research at the point where it is needed. This procedure will avoid costly repetition.

The research man should point out the manufacturing losses, and indicate the necessary investigative work whereby these losses will possibly be reduced or eliminated. These results should not be stored in the records of one company but be available to other manufacturers, so that they can profit by the experience and findings of their neighbors. The petroleum industry, valued at billions of dollars annually, is essential to national efficiency, and national efficiency can be attained only through scientific research. Many petroleum organizations have scientific bureaus, but much of the knowledge these bureaus gain is confined in the archives of the company's laboratory. A fraction of the sums spent in medical research would, if expended in petroleum investigations, bring about improved methods that would vastly increase efficiency in the utilization of each barrel of oil. In 1918 the value of the output of crude oil and refined products in the United States was about $2,500,000,000. Certainly the petroleum industry can afford to spend more than has heretofore been spent in research to discover new methods and perfecting those in use, for thereby the recovery of oil will be increased and utilization will be far more efficient. In this way the cost to the consumer will be lessened and a rapidly diminishing commodity, one essential to our existence, will be conserved.

Former Secretary Lane of the Interior Department has pointed out that we are behind the rest of the world in the use of our oil for fuel purposes. We are spendthrifts in this as in other of our natural resources. We can get three times as much energy as we do out of our oil through the use of the Diesel engine, yet we are doing little to promote development of a satisfactory type of stationary Diesel, or marine design. Instead of seeing how many hundred millions of barrels of oil we can produce and use, our effort should be to see how few millions of barrels will satisfy our needs.

[1]From an address by Van H. Manning, director of the Bureau of Mines, Washington.

Addresses at the Kansas City Tractor Dinner

THE dinner of the Society in connection with the annual Tractor Show at Kansas City, Mo., was held at the Hotel Baltimore in that city on Feb. 19. The principal speakers were J. W. Perry, president of the Commerce Trust Co., and R. F. Crawford, president of the Kansas City Tractor Club.

ADDRESS OF J. W. PERRY

WHILE I cannot discuss the automotive business intelligently from an engineering viewpoint, I feel that our interests are mutual because I can lay before you the needs of the farmer, and also bring to you the views and experiences of the banker, now handling to some extent both the manufacturing and distributing departments of this business. You represent the most advanced ideas and the most practical knowledge of automotive engineering of any body of men in the world. You are the planners and builders of the most up-to-date power machinery ever built by man. You are placing in our hands the instruments with which we hope to produce more of the products of our farms at less cost and to lighten our burden by a decrease in the manpower employed. You are attempting to show us that the motive-power machinery you produce will do more with less expense than man-and-mule power has heretofore accomplished. So far, my experience has been in favor of the man and the mule.

The possibilities for advancement and profit through your work are unlimited. We appreciate these possibilities and welcome them, but we have a right to know that we will be properly equipped. We want to know that you possess the creative genius, the business ability and the mutual interest, that will bring to us a product that can be used to advantage. The automobile industry, some ten years ago, passed through this same creative period. The bankers then had some doubts of its economic value, but these have passed and we now think of it as one of the great and important industries of the country. The public paid the price of creating and making the automobile an aid to civilization and industry. It is profoundly wished that you will now bring to us the farm power machine that can be used to advantage, less the cost of experimentation through which the automobile was made useful. It will not be difficult to finance either the manufacture or the distribution of your product, if we are assured of the adaptability of your machines to our needs, and if they are so constructed as to make their use economical. The tractor and other power machines should be just as universally used as the automobile.

I am one of your customers in the tractor line, having been the first user of a power machine in the neighborhood of my farm. My experience was only partially satisfactory. I feel that I paid the price of your experimentation. I purchased a machine that looked adequate and promised well on paper. My mistake was in trying to run a power machine with a mule driver. The agent's statement that the machine was perfectly simple and easy to operate, in fact almost fool-proof, was erroneous. The machine was powerful and when properly adjusted was capable of doing the work of several teams, but I tried to make it do all the work on the place, treating it as a piece of iron and steel and thinking of it as having been made to run forever. I was soon disappointed. The trouble was that when I purchased my machine I did not buy knowledge. The salesman did not sell me the information that I was entitled to, hence my heavy repair bills and unsatisfactory service.

However, the machine served its purpose, and convinced me that a machine properly built and properly sold is a great labor saver. I wanted to know all the good points of my power machine. I plowed all kinds of ground, pulling the drag behind, put in fall crops, baled hay, cut ensilage, threshed, shelled corn, ground feed, sawed wood and dragged the roads. I tried to do what you must finally accomplish, make this power machine work the entire year. I wanted a universal machine, one that would work all the time and do all the work. To accomplish this, we must first have a machine that is adapted to our soil, in fact to all our needs. The man who builds the universal power farm machine that fills the same place as that of the Ford car in the automobile world will be doing humanity a valuable service. I must not overlook the cost consideration; the cost must be made a minimum and not maximum. You must sell us the kind of machine we need, at the right cost; you must also sell *service*. If I had been properly advised as to the capabilities of my first tractor and if my machine had been properly maintained, my experience would have been more satisfactory. Do not sell a machine without selling knowledge with it; it will not run itself; therefore, sell service also. A satisfied customer is your best agent.

The banker will grant liberal credits on the assumption and proof that the foregoing statements and suggestions are carried out. You will not sell your product on present prices for farm products. All human agencies are now working to reduce high costs. You can have a double part in this by selling your product at the lowest prudent cost and by making your product the means for an increased production. It has been estimated that about $90,000,000 worth of farm implements, including power machinery, was sold during the past year. This is a very large sum, but if properly expended it should bring satisfactory returns. In no other line, however, do I know of any such waste as in farm machinery. Go where you will and you will see the best farm machinery ever placed in the hands of man subjected to the most destructive treatment; no care given to up-keep, the machines exposed to the elements the year around and no thought given to the possibility of making the life of an implement long. This is one of your tasks.

The banker will look with more favor on the time-payment plan when he is assured that the machines you

make and sell will be cared for. The principal thing you should have in mind is to produce a labor-saving device that will make for more economical production. Farm labor is getting scarce and for the most part less desirable. It would seem that the Creator made a long day in summer so that man might have more time to make and harvest a crop; but the would-be rulers and dictators of labor have decreed that there shall be less work and more pay, without thought of the equities or necessities of the majority of mankind. Let us not minimize the importance of labor, for we should all be laboring in some field. The man who toils is always entitled to a fair share of the fruits of his labor, but we cannot make and save a crop in this changeable climate with our limited supply of human help in an eight-hour day and therein lies your opportunity.

ADDRESS OF R. F. CRAWFORD

THE needs of the tractor industry are many. I shall speak from the sales standpoint. I come in contact with the tractor industry in many ways and get the views of a great many people who see it from many different angles.

One of the first things needed in the tractor industry is to make standardized tractors. The more different models of tractors there are, the greater the sale of tractors is hindered. Take, for instance, the types of tractors that are on exhibition at the Tractor Show. A visitor, whether he be a dealer or a farmer who has never used or handled a tractor before, becomes so puzzled by the varied tractor types he sees and the conflicting advice he is given that he has great difficulty to decide what tractor to buy. I do not mean by this that all tractors should be alike, but I wish to show that all these different types and practices are hindering the progress of the tractor industry.

Some of the tractors this visitor has examined are very complicated. All of them look complicated to the man who has yet to learn their mysteries. We do not realize how mysterious these things appear to the man who has not yet been initiated. Some very intelligent people are densely ignorant of the operation of gasoline or kerosene engines. A friend of mine, a car owner, divulged the fact that he did not know what the gasoline did to make the engine go; he knew nothing about how it operated. Another gentleman of my acquaintance, who has owned and used cars for years, went to see a cut-out exhibit of an engine and for the first time in his automobile experience learned the principles of its operation.

It is necessary that engineers work to simplify engines. The fewer things that a farmer has to adjust, the easier it will be for him to operate his tractor and the less expense the manufacturer will have to incur in the way of service. The engineer who develops an engine that is so simple that it is but a matter of a few hours' time for a man of average intelligence to learn its principles and how to operate it, will reap a reward that will fully repay him for the effort. If engineers would consult the sales department when preparing to design a new tractor model I believe they would gain something. The sales department can frequently make suggestions that will avoid having a machine brought out that is not properly balanced. It may be all right from an engineering and a manufacturing standpoint, but all wrong from a sales standpoint; or, it may be all right from the sales and engineering standpoints but all wrong from the standpoint of manufacturing. Combining the three requirements is not easy, but an effort to do it is worthy of any engineer's time.

It may be that it is impossible to simplify the designs of engines and at the same time retain all the good features that engineers feel must be embodied in an engine to make it successful. I feel very sure, however, that it is possible to standardize and simplify the types of tractors until there will be very little more difference between tractors than between the different automobiles of today. Engineers who are designing tractors can learn a good lesson from the way in which automobile designers have proceeded. In general automobile construction is along lines that do not make it so puzzling to users as the tractor seems to be.

It is true that the automobile engine is not worked to its limit of power all the time as is the engine on a tractor. It does not have the same dead load to carry and always has some reserve power. The man who makes provision in the design of a tractor engine to overcome its inclination to give trouble under its dead load, and makes it continue its operation in the same reliable way that an automobile engine does, will have gone a long way toward decreasing the amount of effort that is now required to sell tractors. Tractors are being sold extensively and the supply is not equal to the demand, but the fact remains that a much greater effort is necessary to sell a tractor than to sell an automobile. We all understand that this is not wholly due to the things I have mentioned in connection with the tractor, for the automobile is a pleasure proposition and the tractor is looked upon as an investment, but I am very confident that tractor sales would be doubled if tractors were standardized and simplified to the extent that automobiles have been.

The tractor industry, as a whole, would be greatly benefited if the criticism now indulged in by engineers of competitive types of tractors could be entirely eliminated. If tractor engineers would take a broad-gaged view of all the different types of tractors that are now being built, and in discussing the different types and models be frank enough to refer to the model that differs from theirs as merely a different type of tractor and not disparage it, the prospective purchaser of a tractor would have more confidence in tractors. I know it to be a fact that some engineers can see nothing good in their competitors' designs and are quick to criticise them and pronounce them no good. To criticise a competitor's tractor is to damage the tractor industry, hinder its progress and make harder work for the sales department. Just so long as engineers indulge in criticism as they do today, just so long this extraordinary effort at selling tractors will be necessary. This applies also to manufacturers and those who allow their salesmen to criticise their competitors' machines are creating doubt in the prospective purchaser's mind as to whether or not he wants a tractor, and causing him to wonder whether any of them is worth purchasing.

Applicants *for* Membership

The applications for membership received between April 7 and 23, 1920, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ABELL, HARRY C., plant engineer, Laminated Shim Co., 533 Canal Street, *New York City.*

ALTENBERG, ALFONS, mechanical engineer, Kohler Co., *Sheboygan, Wis.*

BABBITT, PERCY W., research engineer, Simms Magneto Co., *East Orange, N. J.*

BABEL, ELMER H., designer, Duplex Truck Co., *Lansing, Mich.*

BAKER, LOUIS M., sales supervisor, Hyatt Roller Bearing Co., *Detroit.*

BARTELLA, FRANK JOHN, manager equipment sales, A. R. Mosler & Co., *Mt. Vernon, N. Y.*

BEARD, H. P., salesman, Ericsson Mfg. Co., Century Building, *Chicago.*

BECHMAN, O. W., designer, tractor works, International Harvester Co., 2600 West Thirty-first Boulevard, *Chicago.*

BENSON, K. V., assistant foreman, Overland-Harper Co., *Philadelphia.*

BIXBY, L. A., chief draftsman and engineer, Fuller & Sons Mfg. Co., *Kalamazoo, Mich.*

BLACK, DONALD R., designer, L. W. F. Engineering Co., *College Point, N. Y.*

BOYD, CHARLES F., chemist and metallurgist, LaFayette Motors Co., Mars Hill, *Indianapolis.*

BRADY, ARTHUR C., designing engineer, Curtiss Engineering Corporation, *Garden City, N. Y.*

BRASIER, H. E., service manager, Willys-Overland, Ltd., *Toronto, Ont., Canada.*

CARLSON, RAYMOND A., draftsman, Rockford Drilling Machine Co., *Rockford, Ill.*

CARRITTE, J. P., JR., metallurgist, McAdamite-Aluminum Co., *Detroit.*

CAST, J. F., assistant manufacturers, sales manager, Firestone Tire & Rubber Co., *Akron, Ohio.*

CLAWSON, FREDERICK A., salesman, Ericsson Mfg. Co., Century Building, *Chicago.*

COAPMAN, J., chief engineer, Denby Motor Truck Co., *Detroit.*

COCHRANE, WILLIAM F., president, Curtis Bay Copper & Iron Works, *South Baltimore, Md.*

CONROY, FRANCIS R., superintendent, Wisconsin Parts Co., *Oshkosh, Wis.*

CONTOIS, ELY J., tool engineer, Clark Equipment Co., *Buchanan, Mich.*

CRAMNELL, J. C., engineer, Cramnell Steel Co., Sincener Building, *Cleveland.*

CRITCHFIELD, R. M., assistant chief engineer, Dyneto Electric Corporation, *Syracuse, N. Y.*

DALRYMPLE, FITZWILLIAM, JR., student, Century Plainfield Tire Co., *Plainfield, N. J.*

DELONG, B. H., metallurgical engineer, Carpenter Steel Co., *Reading, Pa.*

DIXON, LLOYD A., production manager, Wisconsin Parts Co., *Oshkosh, Wis.*

DOANE, C. W., district representative, Westinghouse Electric & Mfg. Co., 1109 Kresge Building, *Detroit.*

DOBLE, ABNER, engineer, Doble-Detroit Steam Motors Co., *Detroit;* Wm. L. Hughson Co., San Francisco; Standard Gas Engine Co., Oakland, Cal.

DULANY, GEORGE WILLIAM, JR., president, Climax Engineering Co., *Clinton, Iowa.*

DUNBAR, H. L., salesman, Standard Steel & Bearings, Inc., *Philadelphia.*

EKBLAW, K. J. T., engineering editor, Phelps Publishing Co., Orange Judd Co., *Chicago.*

FERGUSON, MALCOLM P., service engineer, Eclipse Machine Co., *Elmira, N. Y.*

FERRIS, W. E., secretary and treasurer, Ohio Motor Vehicle Co., *Cleveland.*

FINKE, CHRIS J., draftsman, Watson Products Corporation, *Canastota, N. Y.*

FITZGERALD, HAROLD R., designer, Winton Co., *Cleveland.*

GESSLER, CARL W., P. O. Box 851, *Porterville, Cal.*

HAGGART, J. C., JR., assistant chief engineer, Republic Motor Truck Co., Inc., *Alma, Mich.*

HARRSCH, WILLIAM GEORGE, secretary and treasurer, Highway Motors Co., *Chicago.*

HELRIEGEL, ROBERT G., service manager, Hahn Motor Truck Co., *Hamburg, Pa.*

HELWIG, BEN G., chief engineer and treasurer, Betz Motor Truck Co., *Hammond, Ind.*

HERZOG, JOHN A., chief draftsman, Reo Motor Car Co., *Lansing, Mich.*

HILTON, GABE, service department, Wisconsin Parts Co., *Oshkosh, Wis.*

HOAGG, KIRKE K., mechanical engineer, Hyatt Roller Bearing Co., *Detroit.*

HODGE, EDWIN, JR., vice-president, Pittsburgh Knife & Forge Co., *Pittsburgh.*

HUANG, SHOU-HENG, consulting engineer, Alexander Klemin, 22 East Seventeenth Street, *New York City.*

JOHNSON, ARTHUR GRANT, salesman, West Steel Casting Co., *Cleveland.*

JOHNSON, R. F., mechanical engineer, Iron Mountain Co., *Chicago.*

KEESE, B. W., tool designer, Wisconsin Parts Co., *Oshkosh, Wis.*

KING, CHARLES D., chief engineer, Killington Machine Co., *Syracuse, N. Y.*

KING, W. A., president and general manager, Southern Automobile Mfg. Co., *Houston, Texas.*

KIRBY, HARLEY E., sales engineer, Electric Storage Battery Co., *Chicago.*

KLAUS, FRED R., general manager and vice-president, Cleveland Welding & Mfg. Co., *Cleveland.*

KLOSSNER, ROBERT, student, Michigan State Auto School, *Detroit.*

KNAPP, KARL M., Pittsburgh representative, Cyclops Steel Co., *Titusville, Pa.*

LAMB, ERNEST P., draftsman, Central Axle Co., *Detroit.*

LANG, ELMER J., vice-president and general manager, Lang Body Co., *Cleveland.*

LANGE, EDWARD CO., consulting engineer, Franco Asiatic Trading Co., *Shanghai, China.*

LAVISTE, FRANK W., experimental engineer, L. W. F. Engineering Co., *College Point, N. Y.*

LEACH, HAL W., estimating engineer, Holt Mfg. Co., *Peoria, Ill.*

LOWNDES, JOHN M., superintendent of mechanical transport, Department of Soldiers' Civil Re-establishment, *Ottawa, Canada.*

LUTEY, WILLIAM, body engineer, Lang Body Co., *Cleveland.*

LYON, NORMAN WILLIAM, assistant engineer, Knox Motors Co., *Springfield, Mass.*

MCBETH, JAMES R., chief draftsman, Gramm-Bernstein Motor Truck Co., *Lima, Ohio.*

MARTIN, ROBERT H., secretary, treasurer and general manager, Southern Oakland Co., *Atlanta.*

MEAD, GEORGE E., factory manager, Van Blerck Motor Co., *Monroe, Mich.*

MITNICK, JACOB J., automobile engineer, Armour Institute of Technology, *Chicago.*

MOORE, GEORGE T., sales engineer, Wisconsin Parts Co., *Oshkosh, Wis.*

MORGAN, E. K., general superintendent, Rockford Drilling Machine Co., *Rockford, Ill.*

MURPHY, R. L., purchasing agent, Wisconsin Parts Co., *Oshkosh, Wis.*

OLSON, GUST, JR., assistant general superintendent, Root & Van Dervoort Engineering Co., *East Moline, Ill.*

POLITANO, THEODORE M., draftsman, Ward Motor Vehicle Co., *Mount Vernon, N. Y.*

PRICE, W. T. R., automotive engineer, International Motor Co., *New York City.*

PURRINGTON, D. D., assistant superintendent, Standard Oil Co., 200 Bush Street, *San Francisco.*

RADFORD, FRED L., assistant engineer, Reo Motor Car Co., *Lansing, Mich.*

REES, FRED H., sales manager, Willys-Overland, Inc., *New York City.*

RICHARDSON, GEORGE ATWELL, in charge of advertising and publication work, Midvale Steel & Ordnance Co., Cambria Steel Co., *Philadelphia.*

ROCHE, CLIFTON ROSS, automotive engineer, Hamlin-Holmes Motor Co., *Chicago.*

ROUSE, W. BRYAN, chief draftsman, Lack Mfg. Co., *Paducah, Ky.*

RUSSELL, R. S., in charge of designing, Handley-Knight Co., *Kalamazoo, Mich.*

SALADIN, HARRY J., vice-president, Glenmore Co., *Lima, Ohio.*

SEABURY, W. W., engineer, LaFayette Motors Co., Mars Hill, *Indianapolis.*

SHERWOOD, GEORGE E., sales engineer, Doehler Die-Casting Co., *Brooklyn, N. Y.*

SHOEMAKER, FRED GLENN, experimental engineer, Buda Co., *Harvey, Ill.*

SHOEMAKER, HERVY B., research engineer, Central Axle Co., *Detroit.*

SIMPSON, CARL W., metallurgist, American Axle Division, Standard Parts Co., *Cleveland.*

SMILEY, RUSSELL A., chief inspector, L. W. F. Engineering Co., Inc., *College Point, N. Y.*

SMITH, ROY H., secretary, treasurer and general manager, Falls Rivet Co., *Kent, Ohio.*

SNYDER, JAMES H., draftsman, Selden Truck Corporation, *Rochester, N. Y.*

SOSS, CHARLES J., treasurer, Soss Mfg. Co., Grand Avenue and Bergen Street, *Brooklyn, N. Y.*

STENGEL, H. IVAN, service engineer, Detroit-Cadillac Motor Car Co., 1881 Broadway, *New York City.*

STOCKER, WILLIAM M., mechanical engineer, Poole Engineering & Machine Co., *Baltimore.*

STRAUS, ADOLPH, mechanical engineer, Pittsburgh Model Engine Co., *Pittsburgh.*

TORREY, DANA H., sales manager, Bearings Service Co., *Detroit.*

TRASK, HENRY KEITH, works manager, Clark Tractor Co., *Buchanan, Mich.*

VANDERLIPP, N. F., draftsman, Alexander Klemin, 22 East Seventeenth Street, *New York City.*

WATERMAN, DONALD F., mechanical designer, Brewster & Co., *Long Island City, N. Y.*

WEBB, PAUL ST. ELMO, transportation engineer, Diamond T Truck Co., Inc., *Nashville, Tenn.*

WHITAKER, NORMAN T., patent lawyer, Whitaker Building, *Washington.*

WILSON, H. D., vice-president, Herschell-Spillman Motor Co., *North Tonawanda, N. Y.*

WILSON, LESTER T., technical representative, National Lead Co., *Brooklyn, N. Y.*

WOODS, WALTER H., sales engineer, Hyatt Roller Bearing Co., *New York City.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between April 1 and 17, 1920. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (E S) Enrolled Student; (S M) Service Member; (F M) Foreign Member.

BRAUTIGAM, H. H. (M) secretary and manager, Bridgeport Motor Co., *Bridgeport, Conn.*

BRUNTON, S. L. (F M) manager, Hadley Castle Works, c/o Joseph Sankey & Sons, Ltd., *Wellington, Shropshire, England.*

BUCKMASTER, BEN STALKER (M) engineer, Chicago district, industrial bearings division, Hyatt Roller Bearing Co., Detroit (mail) 1643 East Sixty-seventh Street, *Chicago.*

BURNS, WILLIAM T. (M) automotive engineer, Timken Roller Bearing Co., *Canton, Ohio.*

CAVANAGH, JAMES F. (A) president and general manager, Northway Motors Corporation, Natick, Mass. (mail) 1 Beacon Street, *Boston.*

CHORLTON, HERBERT (A) experimental engineer, Brewster & Co., Long Island City, N. Y. (mail) *Huntington Station, N. Y.*

CONWAY, ARTHUR W. (A) service engineer, Splitdorf Electrical Co., 98 Warren Street, *Newark, N. J.*

DEERING, JOSEPH L. (A) Canadian sales department, Aultman & Taylor Machinery Co., Mansfield, Ohio (mail) 1930 Montague Street, *Regina, Sask., Canada.*

DYSART, WILLIAM L. (A) manager and engineer, Harlowton Grocery Co., Inc., *Harlowton, Mont.* (mail) Box 1515.

EVANS, LLOYD L. (A) patent engineer, Hydraulic Pressed Steel Co., 1878 East Fifty-ninth Street, *Cleveland.*

FLAMAND, KNUD (A) production superintendent, Merchant & Evans Co., 2035 Washington Avenue, *Philadelphia.*

GARDNER, LEVI S. (M) vice-president and general manager, Gardner Carburetor & Brass Works, *Detroit.*

HILL, LYMAN L. (J) assistant to chief engineer, Air Service, *Dayton, Ohio* (mail) 27 South Becket Street.

HOFFMAN, WILLIAM P. (A) chief inspector, Cleveland Automobile Co., *Cleveland* (mail) 1416 East Eighty-second Street.

JACKSON, CHARLES A. (M) treasurer and general manager, Jackson Electric Co., 711 Beacon Street, *Boston.*

KENWORTH, ROBERT J. (A) salesman, Standard Parts Co., Cleveland (mail) Standard Parts Co., 616 West Fifty-sixth Street, *New York City.*

MCFARLAN, A. H. (M) president and factory manager, McFarlan Motor Co., Mount and High Streets, *Connersville, Ind.*

MADSEN, THOMAS EVANS (J) draftsman and layout man, Milburn Wagon Co., Toledo, Ohio (mail) 4023 Peak Avenue, *West Toledo.*

MEALEY, THOMAS A. (A) salesman, Standard Parts Co., Cleveland (mail) 28 Ogden Street, *Trenton, N. J.*

MICHAEL, GUS F. (J) assistant engineer, South Bend Motors Co., *South Bend, Ind.*

MILLER, ROY G. (M) physicist, National Advisory Committee for Aeronautics, Langley Field, *Hampton, Va.*

MONTGOMERY, ROBERT A. (A) chief draftsman, engineering branch, Motor Transport Corps, *Washington* (mail) 1736 G Street, Northwest.

PENDILL, PIERRE B. (M) chief engineer, Hollis Tractor Co., 1709 Keenan Building, *Pittsburgh.*

PERKINS, L. M. (M) chief engineer, Dyneto Electric Corporation, *Syracuse, N. Y.*

PERSSON, O. F. (M) assistant engineer, gas engine engineering department, General Electric Co., *Erie, Pa.*

PHELPS, ARTHUR G. (A) chief engineer, Elkhart Carriage & Motor Car Co., West Beardsley Avenue, *Elkhart, Ind.*

PIERCE, LESLIE EDWARD (J) Park Avenue Hotel, *New York City.*

POWELL, A. LYLE (J) junior sales engineer, freight transportation division, Packard Motor Car Co., *Chicago* (mail) 7742 North Paulina Street.

RESEL, FRANK J. (A) engineering representative, Fellows Gear Shaper Co., Springfield, Vt. (mail) 4144 Sheridan Road, *Chicago.*

ROBERTS, S. B. (J) assistant mechanical engineer, Bartram Brothers, New York City (mail) Estate San Isidro, *Santo Domingo, Dominican Republic, West Indies.*

ROSS, E. R. (E S) student, Purdue University, Lafayette, Ind. (mail) 208 South Street, *West Lafayette.*

SEXTON, GEORGE L. (M) mechanical engineer, Sexton Agricultural Tractor, *Detroit* (mail) 288 East Milwaukee Avenue.

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